Final Report

Vegetational Status of the Freshwater Tidal Marshes of the Upper Cooper River

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Introduction

South Carolina coastal river systems have a freshwater tidal region that was modified for rice culture during the 18th and 19th centuries. River swamp and marsh were converted to level bottomed fields of nearly uniform depth. Dikes, ditches and trunks controlled water levels. Accounts of the origins of rice culture and the day to day practices of growers are found in Heyward (1937), Hawley (1949), Doar (1970) and Porcher (1985). The industry had ended by the 1920s through loss of the labor force, mechanized production in competing areas and storm damage. Many fields were abandoned. Breaches in dikes allowed the return of daily tidal flow and set in motion an aquatic succession process. Today these fields are found in a variety of successional states. The present condition of individual fields is determined by cultivation history, management practices, time of abandonment, water depth, duration of cover, salinity, and possibly other factors.

Interest in plant species composition, primary productivity and successional processes occurring in these systems can be traced to Wells (1928) and to more recent studies by Baden (1971), Stalter (1972), Baden et al. (1975), Gresham and Hook (1982), Williams et al. (1984), Pickett, McKellar and Kelley (1986), Kelley, Porcher and Michel (1990) and Stalter and Baden (1994). Reports that record biological, chemical and physical data specifically for the Cooper River include Adams (1972), Christie (1978), Curtis and Christie (1983), Homer and Williams (1985), Nelson (1974), U.S. Army Corps of Engineers (1975), Lagman et al. (1980), Williams et al. (1984) and Van Dolah et al. (1990).

As the U.S. Army Corps of Engineer developed plans to reroute some of the Cooper Rivers' freshwater flow to the Santee River (Cooper River Rediversion Project, COE, 1975), models predicted lowered water levels in the Cooper River. This suggested to us the likelihood of accelerated successional change in marsh vegetation. Changes measured in decades in other river systems might be measured in years or even months in the Cooper. The project created an opportunity to document and model the rate and patterns of succession. Observable differences in plant composition, animal presence and human use among the various stages also suggested that successional change might result in the loss (gain) of some functions and uses over time. Beginning in 1977, Kelley & Porcher and later McKellar and others collected prediversion quantitative and observational data in four tidal remnant rice fields in the Cooper system. Status reports were published in 1986 (Pickett, McKellar and Kelley) and 1990 (Kelley, Porcher and Michel). In the present project, our objectives are

1. To produce a species list of all vascular plants collected and observed in our study sites over the 1982-1994 interval.

2. To produce vegetation maps showing the changes in the distribution of plant communities in the study sites over the 1982-94 interval.

3. To compile a ground level and low level aerial photographic record of remnant rice fields on the Cooper system.

4. To propose a successional pattern for Cooper system tidal freshwater marsh.

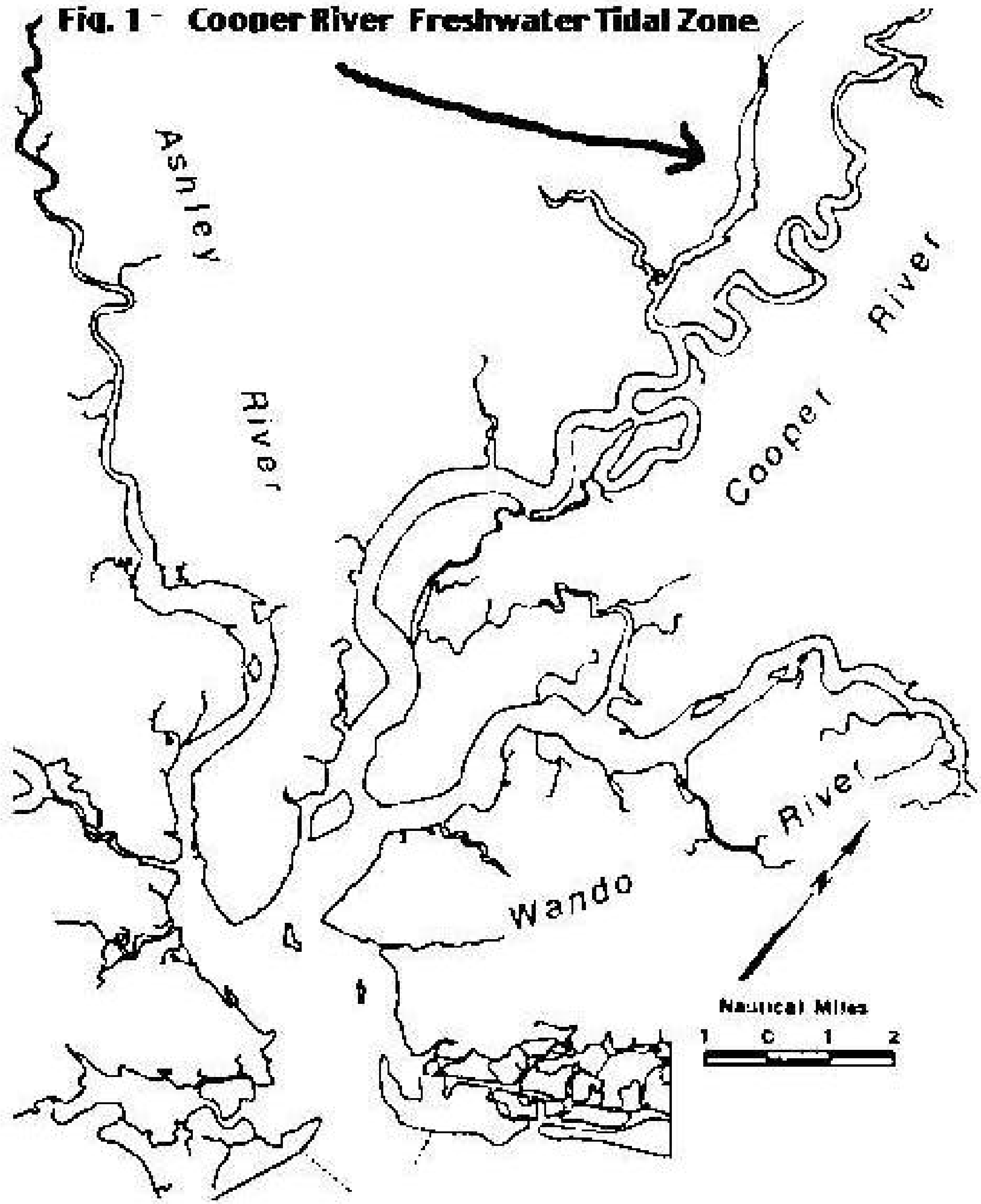
5. To discuss the implications of succession on habitat diversity, ecological function and recreational opportunity in the Cooper system.

6. To identify research problems for future study.

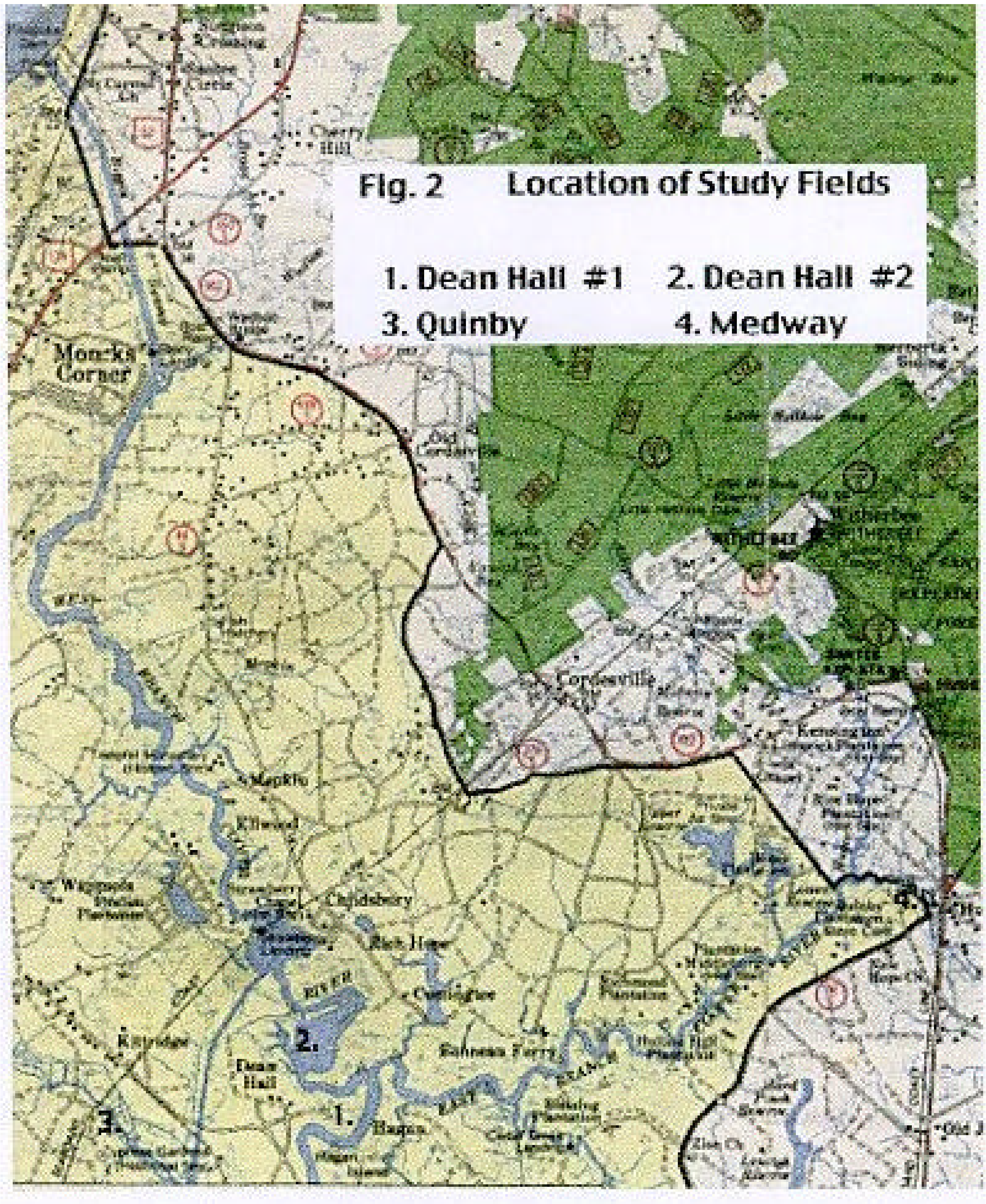
Methods

Study Site/Study Period

In 1985 water levels in the upper Cooper River near Charleston, S.C. (figs. 1 & 2) dropped as much as 15cm (Kelley et al., 1990), as a result of the Cooper River Rediversion Project. In anticipation of vegetational changes in intertidal marsh, Kelley and Porcher (unpublished) and Pickett, McKellar and Kelley (1983) began prerediversion surveys of remnant impoundments along the East and West branches of the Cooper and of the Back River tributary. In 1977-79 Kelley and Porcher identified and visually characterized 80 old rice fields with breached dikes that were open to tidal fluctuation and 21 impoundments with dikes and water control structures still functioning. Pickett, McKellar and Kelley (1986) selected one tidal field, Dean Hall (fig. 2), located at the T (junction of East and West branches) for a detailed vegetation survey and primary production study. Kelley and Porcher (unpublished) collected quantitative species composition and biomass data during the same time period at 3 other locations: Dean Hall #2, Medway and Quinby (Fig. 2). The 4 fields, Dean Hall, Dean Hall#2, Medway and Quinby, were chosen because they appeared to represent a successional series ranging from open water/submergent macrophyte dominated at Dean Hall#2 to grass/sedge dominated with some tree cover at Medway. Kelley, Porcher and Michel (1990) repeated the Dean Hall study in 1989 to evaluate vegetational changes since the 1985 rediversion. Kelley and Porcher also continued sampling at Dean Hall#2, Medway and Quinby in 1988 and 1989. In the present 1994-1995 study Kelley and Porcher have revisited, visually classified and photographed all of the upper Cooper fields surveyed in 1977. We have extended the quantitative species composition and biomass work done earlier at Dean Hall, Dean Hall#2, Medway and Quinby. In this project, we have added low level aerial photography and computerized analysis of digitalized color infrared aerial photography to our study.

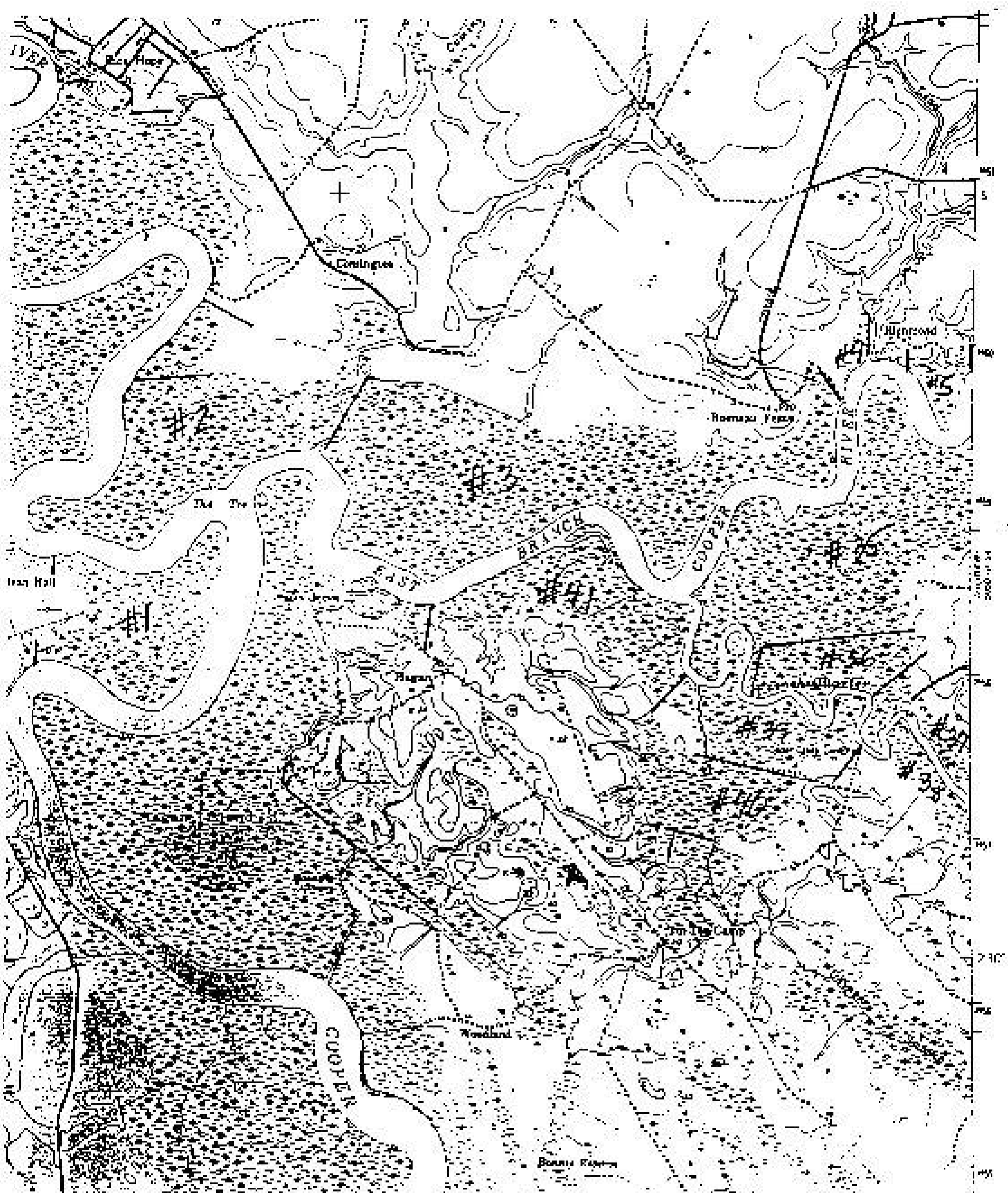


Quantitative field sampling methods: In 1982 and 1989, 25 randomly distributed 1/4m^2 quadrats were collected each month from the Dean Hall field. 10 to 20 random 1/4m^2 quadrats were harvested seasonally at Dean Hall #2, Medway and Quinby during the same time period. In 1994-95, 20 random quadrats were collected from each of the 4 fields during the time of peak community biomass and species abundance (June- September). All quadrats were collected by cutting plant stems at ground level. Samples were sorted to species, dried and weighed. Records of salinity, pH and soil moisture content were recorded at many of the sample sites.



Observational/photographic methods. In 1994 Kelley and Porcher returned to each of the fields visited in 1977-79. A field numbering/identification system is shown in Figure 3. We photographed each field from near ground level and recorded a visual classification of the field to compare with visual classifications made similarly in the late 1970s. In the Fall of 1994 and again in 1995 we photographed the fields from the air (800 - 1200 ft above ground). Flight paths are also shown in Figure 3. Both sets of photography are appended to this report.

Fig. 3 Field Numbering System



ITED STATES
NT OF THE INTERIOR
OGICAL SURVEY
UNITED STATES
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
Irwin Chapel
Upper Reserve
Lower Reserve
Bossis Plantation
Quinby Sch
Quinby Plantation
Huger
New Hope
Pompion Hill Chapel
Middleburg Plantation
Richmond Plantation
Hollon Hill Plantation
COOPER
RIVER
EAST
BRANCH
F R A N C I S
New Hope Sch
#9
#10
#11
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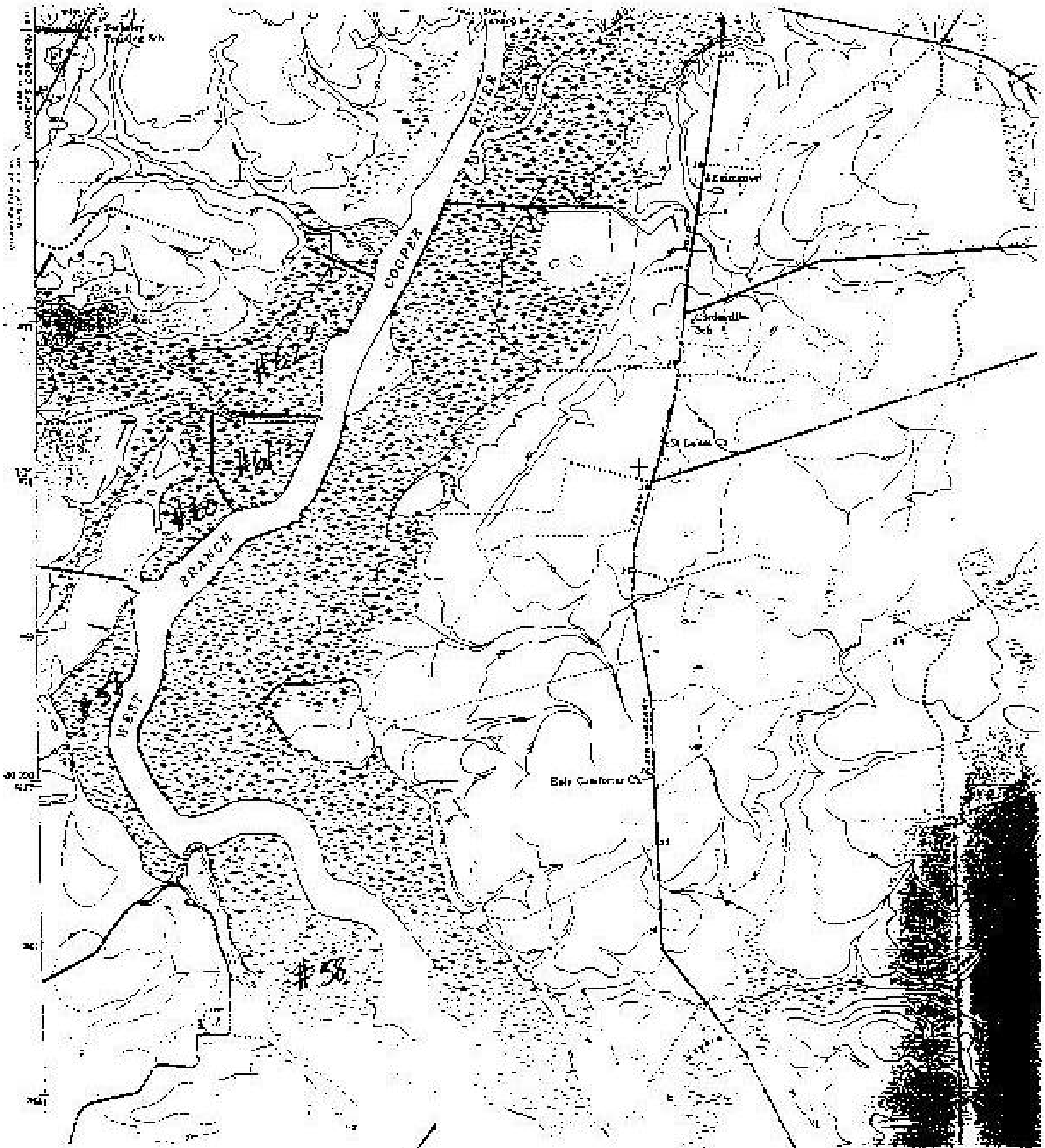
#43
#42
#2
#1
Hopkin
Elwood
Wappoola
BRANCH
COOPER
RIVER
Chilsbury
Strawberry Chapel
Rice Hope
Kittredge
Dean Hall



#57

Tabo Ch
BRANCH
COOPER
RIVER
Strawberry Chapel
Landing
Promised Land Ch
Kittredge
Dean Hall
Cypress
#76
#77

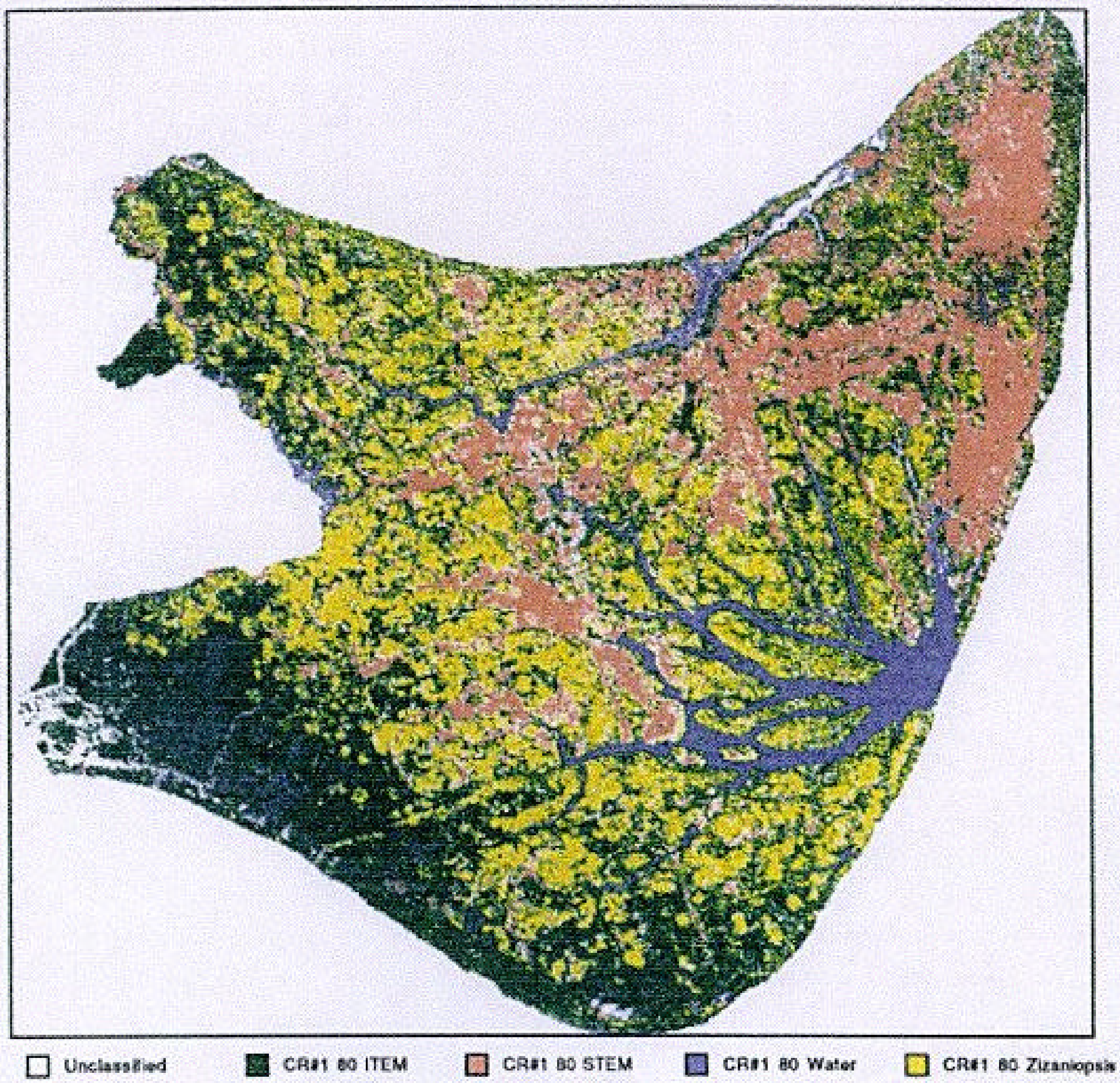
Analysis/classification of color IR aerial photography. Images used include: 1. Color infrared (IR) transparencies (NAPP photography -1/40,000 and other larger scale IR photography) obtained from the S. C. Office of Coastal Resources Management, 2. A digitalized, color balanced, rectified and registered set of 1994 images obtained from the S.C Land Resources Commission and 3. Our own low level Ektachrome slide photography. OCRM photography was scanned on a Topaz commercial scanner at 300DPI and stored on SyQuest 270MB cartridges. Ground coordinates used in rectifying and registering the images were obtained using a S.C. Land Resources Commission Trimble GPS system. Unique patterns of ditches and other landmarks made it possible to match randomly chosen ground sample sites to coordinates on a gridded map and vegetation patches in aerial photos. Low level slide photography and quadrat data were used in confirming community classifications of aerial IR analyses. Image analysis was performed on a MacIntosh 8100 system using Dimple image analysis software.

Results

Dean Hall

Using winter 1981 color IR aerial photography and growing season 1982 ground sampling data, we produced the Dean Hall classification shown in Fig. 4. In 1981-82 the flat intertidal areas between ditches were dominated by either dense stands of Zizaniopsis (called white marsh locally) and Pontederia (pickerel weed), 13.7% cover, or by a more complex mixture of species (called ITEM = intertidal emergent mix) including Pontederia, Lycopus, Alternanthera, Zizaniopsis, Peltandra and others, especially the vines Apios,Cuscuta and Mikania, 20.5% cover. Figures 5 &6 present 1982 species frequency and July 1982 biomass data summaries. 29 species were collected in quadrat samples with 90% of the biomass being concentrated in 10 species. Soils were saturated at all tides and salinity measured with a refractometer was never above 0. Soil pH was nearly uniform over the entire field at about 7.6 . Repeated sitings were made of wood ducks, mallards, ibis, coots, gallinules, king rails, great blue herons and red winged blackbirds. Alligators, turtles, bream, bass and mudfish were common in or on the edges

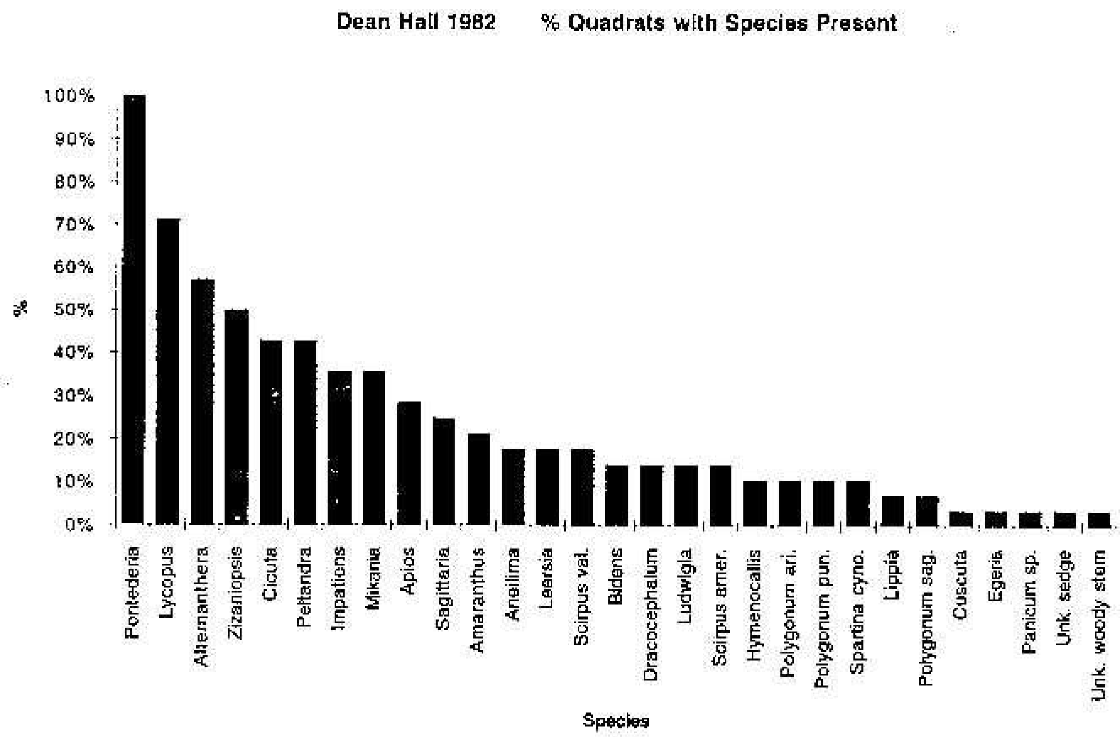
Fig. 4 Dean Hall # 1 Winter 1981



Community	Area (m2)	% Cover
ITEM Mix	256892	20.5
Ludwigia	115639	9.2
Zizaniopsis	171742	13.7

of ditches and cotton- mouth moccasins, fiddler crabs (Uca minax), gammarid amphipods, rabbits and deer in the intertidal flats. Noticeably absent: mosquitos, biting midges, and flies. Peltandra, Zizania, Polygon sp. and other plant species present are known to be attractive foods to various birds (McAtee, 1911, Landers et al. 1976). Ditches were mostly open to boat passage but some shallow areas were being closed by

Fig. 5



the submergent/low emergent Ludwigia uruguayensis. Bass and bream fishermen in boats were regularly seen in the dike breaches and inside the field in the deeper open water ditches. Areas deeper into the field and closed to boat passage were often the places where most of the vertebrate wildlife was found.

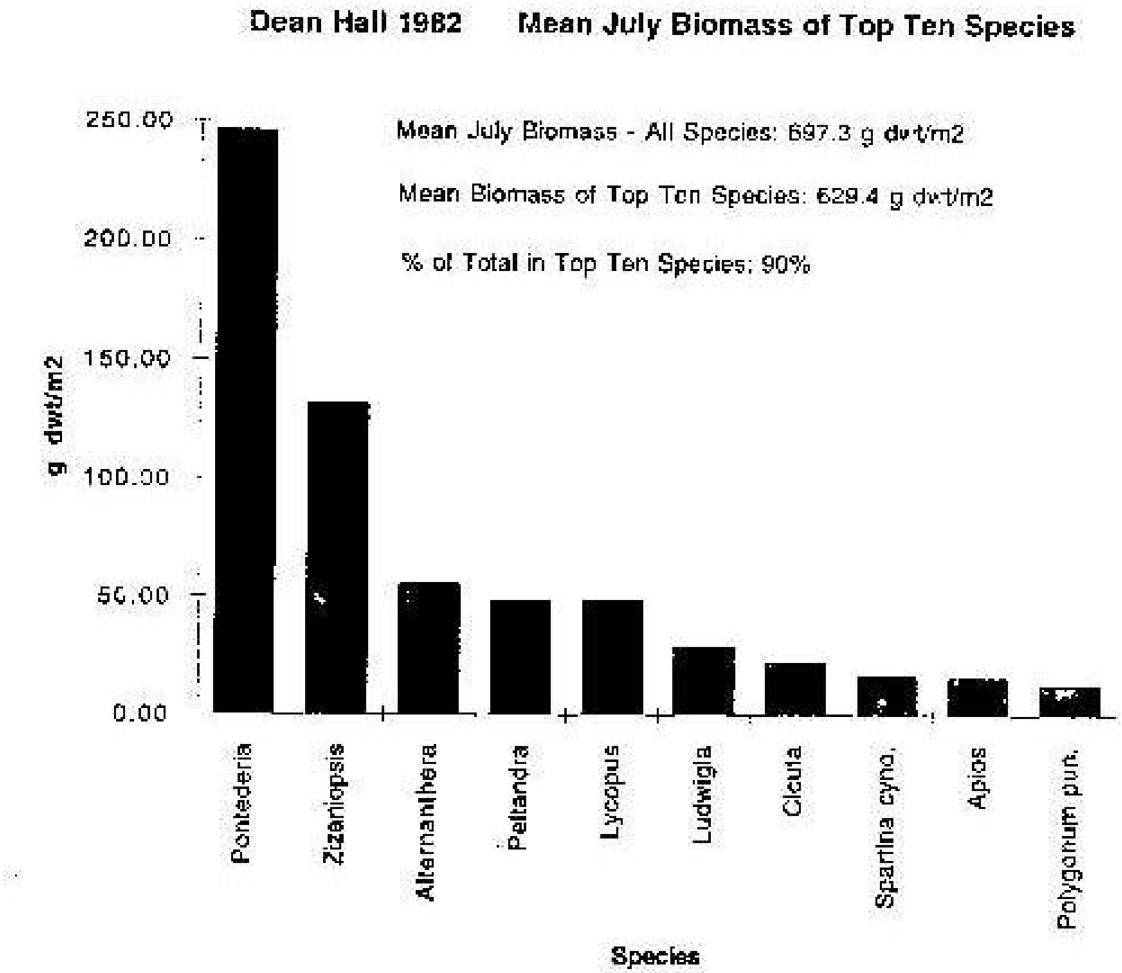
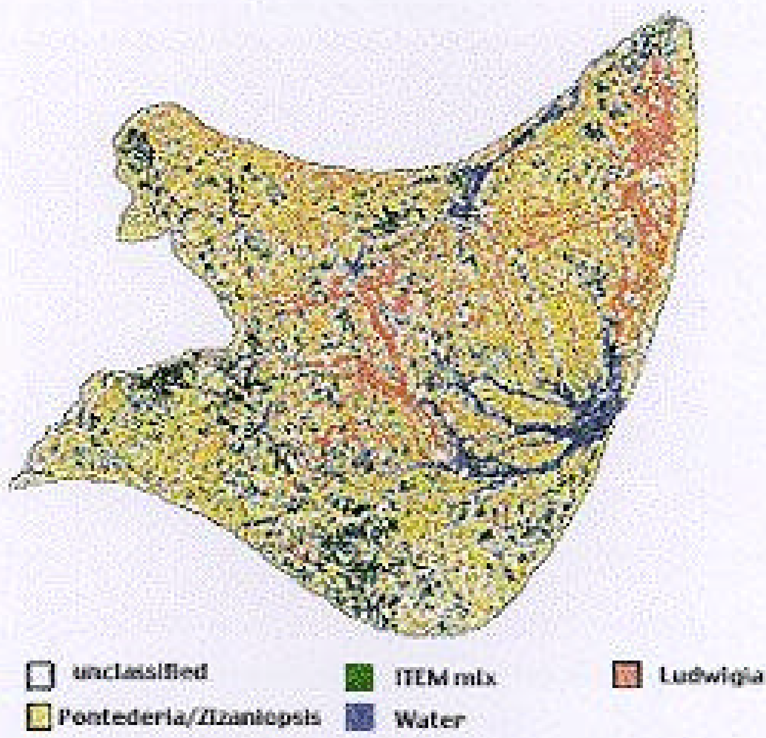


Figure 6

Figure 7 is a classification of a spring (April) 1982 aerial photo taken approximately 14 months after the 1981 winter photo used to produce Fig. 4. It shows the striking difference in community composition and cover associated with seasonal succession. By February in most years, winter die back has reduced the standing green biomass of ITEM areas in the field to flat rosettes of plants like Dracocephalum and Lobelia with Alternanthera often making the largest % contribution to quadrat live biomass. By March new growth of broad leaf perennials like Peltandra, Pontederia, Sagittaria and Cicuta predominates with grasses and sedges; e.g., Zizaniopsis and Scirpus pushing through to form an overstory later in the season. Vines and midstory additions; e.g., Lycopus and Bidens, complete the development of quadrat complexity by June/July. Accurate production estimates take into account the progression of biomass peaks that occur throughout the growing season (Pickett, McKellar and Kelley, 1986).

Fig. 7 Dean Hall # 1 Spring 1982



Community	Area (m2)	% Cover
ITEM Mix	67736	9.5
Ludwigia	76374	10.7
Pontederia/Zizaniopsis	273331	38

No classification figure for 1988-89 is presented for Dean Hall because adequate 1988-89 aerial photography for Dean Hall was unavailable. This is the time period however when intensive field sampling was done at Dean Hall and the following comparisons to 1982 characterizations were reported in Kelley, Porcher and Michel (1990): 1. Water levels had decreased 2. The flora was more diverse 3. The standing crop of some dominants had decreased 4. The cover (frequency) of approximately 1/3 of the species common to both years increased, with most of these being subdominant understory species and 5. Seasonal successional patterns were different. The 1982 dominants Pontederia (pickerel weed), Zizaniopsis (white marsh) and Lycopus were less frequent in 1988 (figs. 5 & 8). White marsh biomass also declined in 1988 (figs. 6 & 9).

Fig. 8

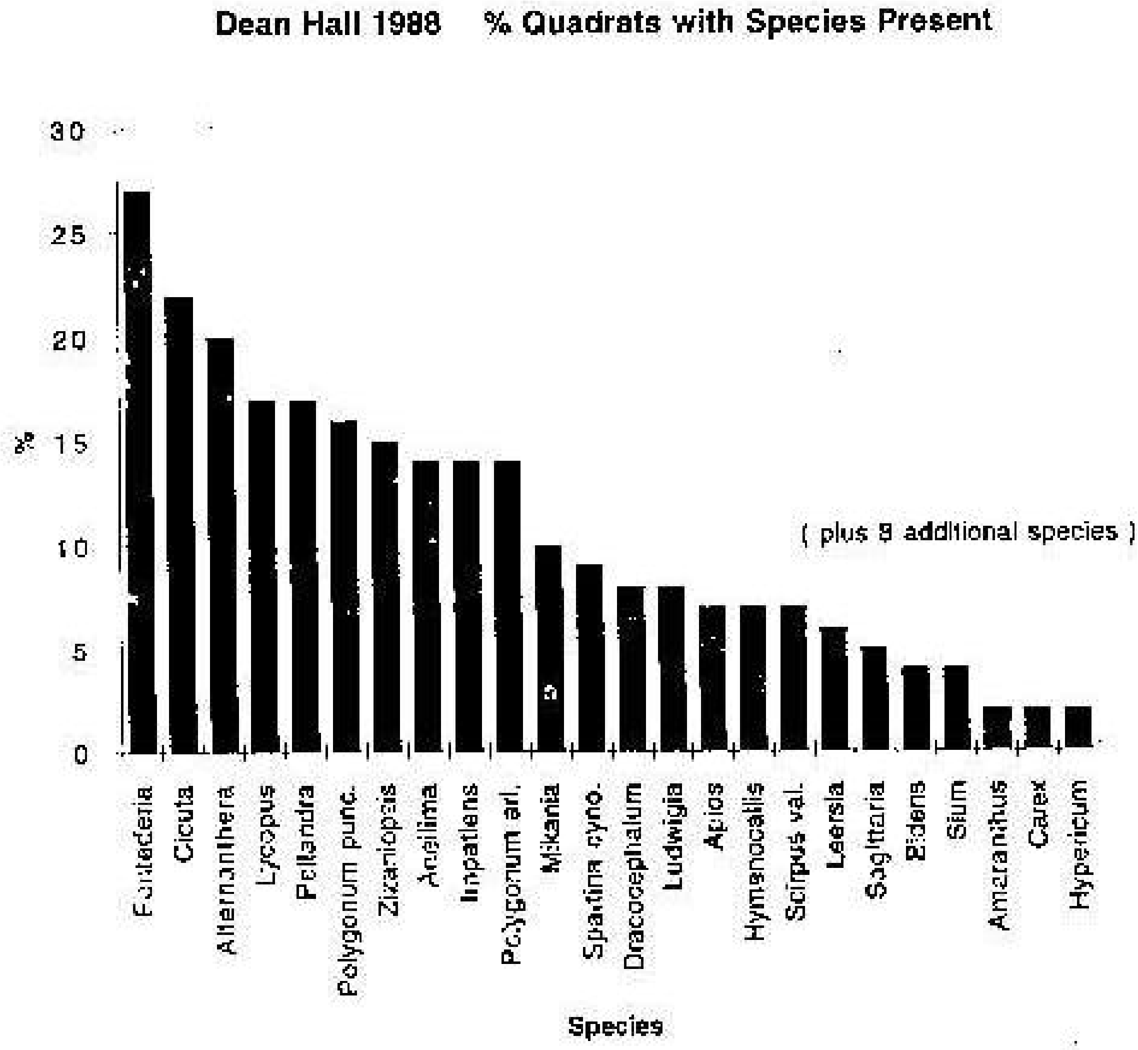


Figure 10 is a classification of Dean Hall as it appeared in 1994 photography. Zizaniopsis dominated quadrats appear to have diminished dramatically from 1982 and 1988 counts. The dominance still shown by white marsh in average biomass (fig. 11) results from the fact that several of the 1994 quadrat samples fell in dense stands of

Zizaniopsis. Standing crop in these dense stands is very high and skewed the biomass data to favor

Zizaniopsis. A similar apparent contradiction seems to exist when 1982 – 1994 Ludwigia frequency and cover are examined (figs. 4, 10 and 12) which is explained

Fig. 9

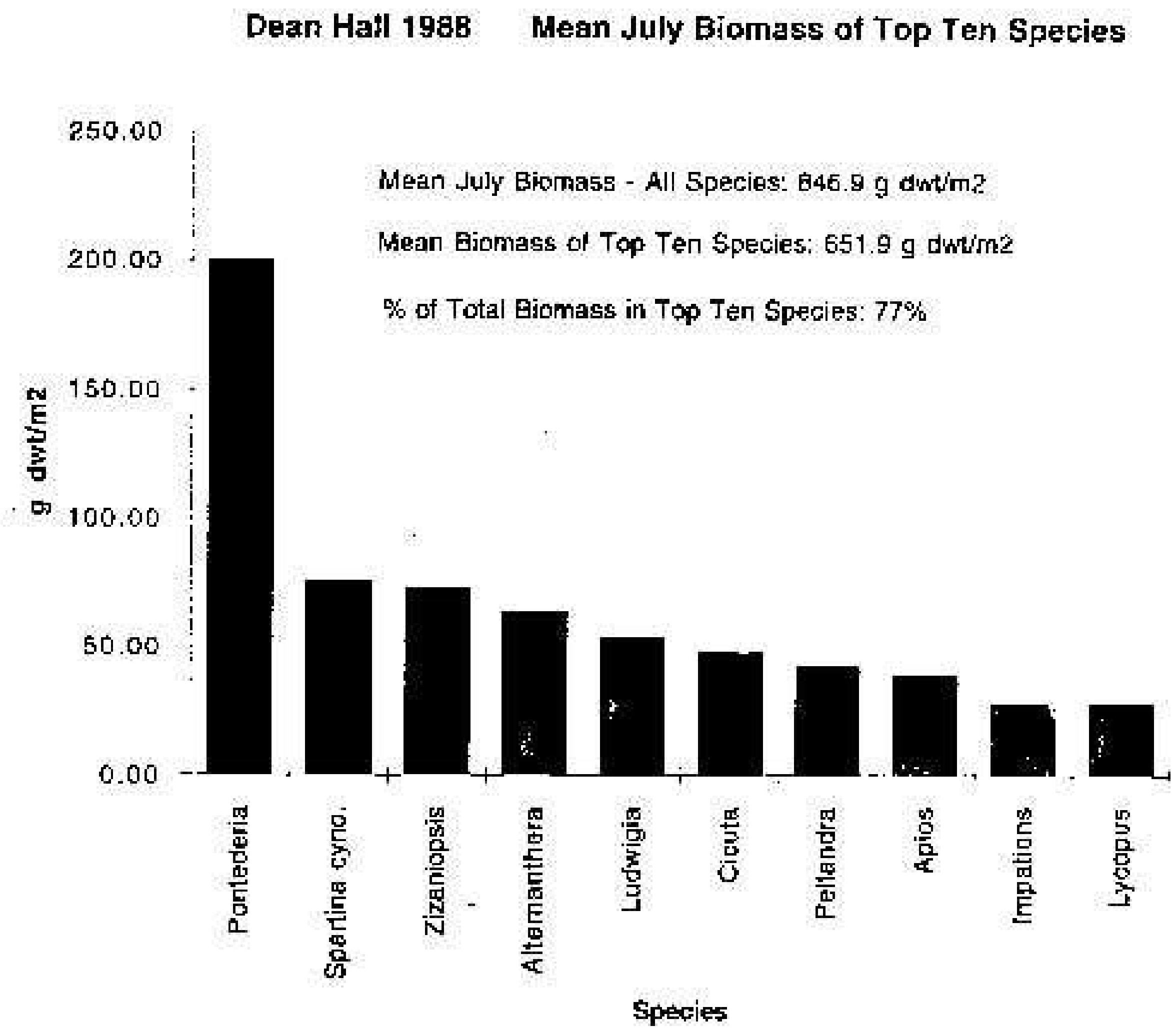
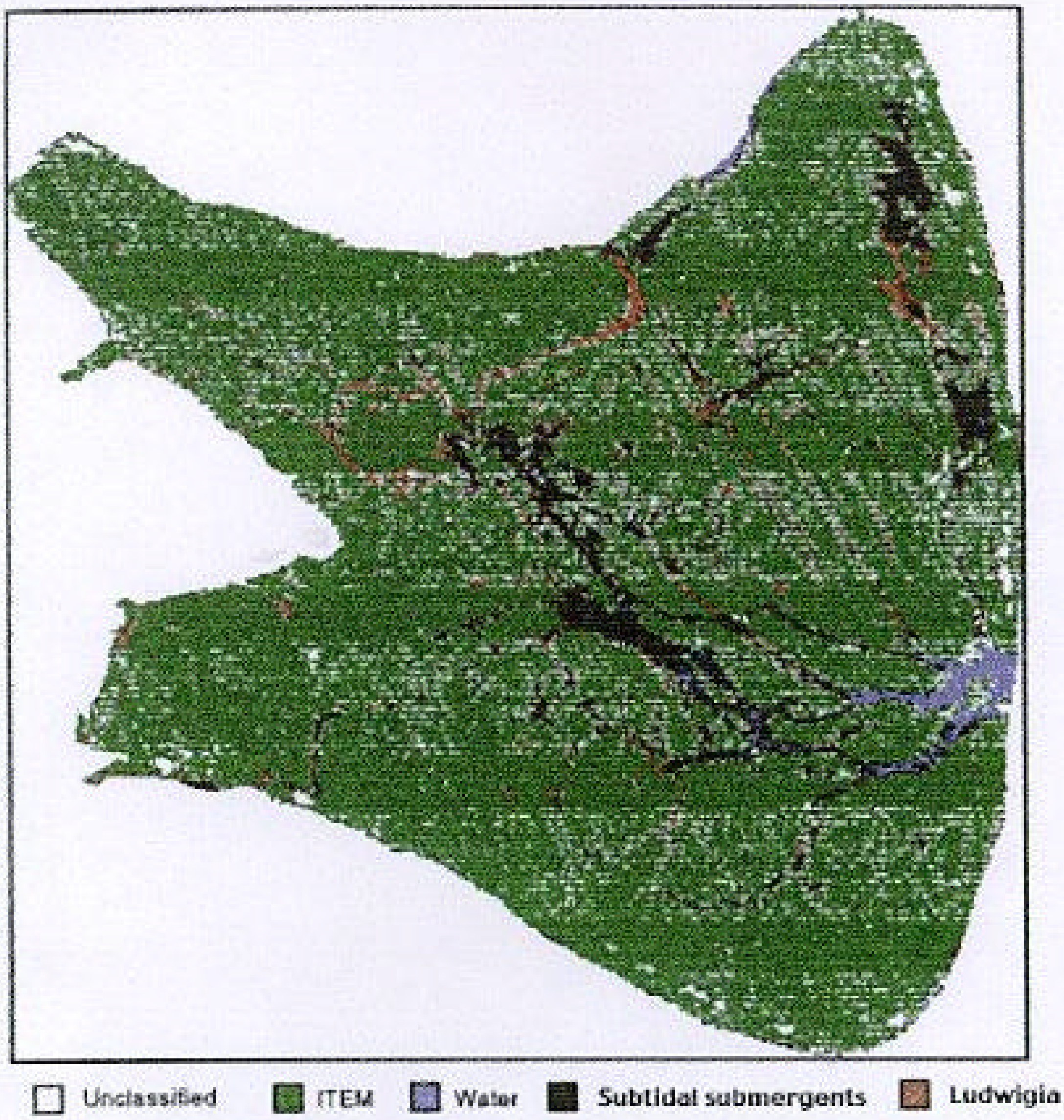


Fig. 10 Dean Hall # 1 Winter 1994

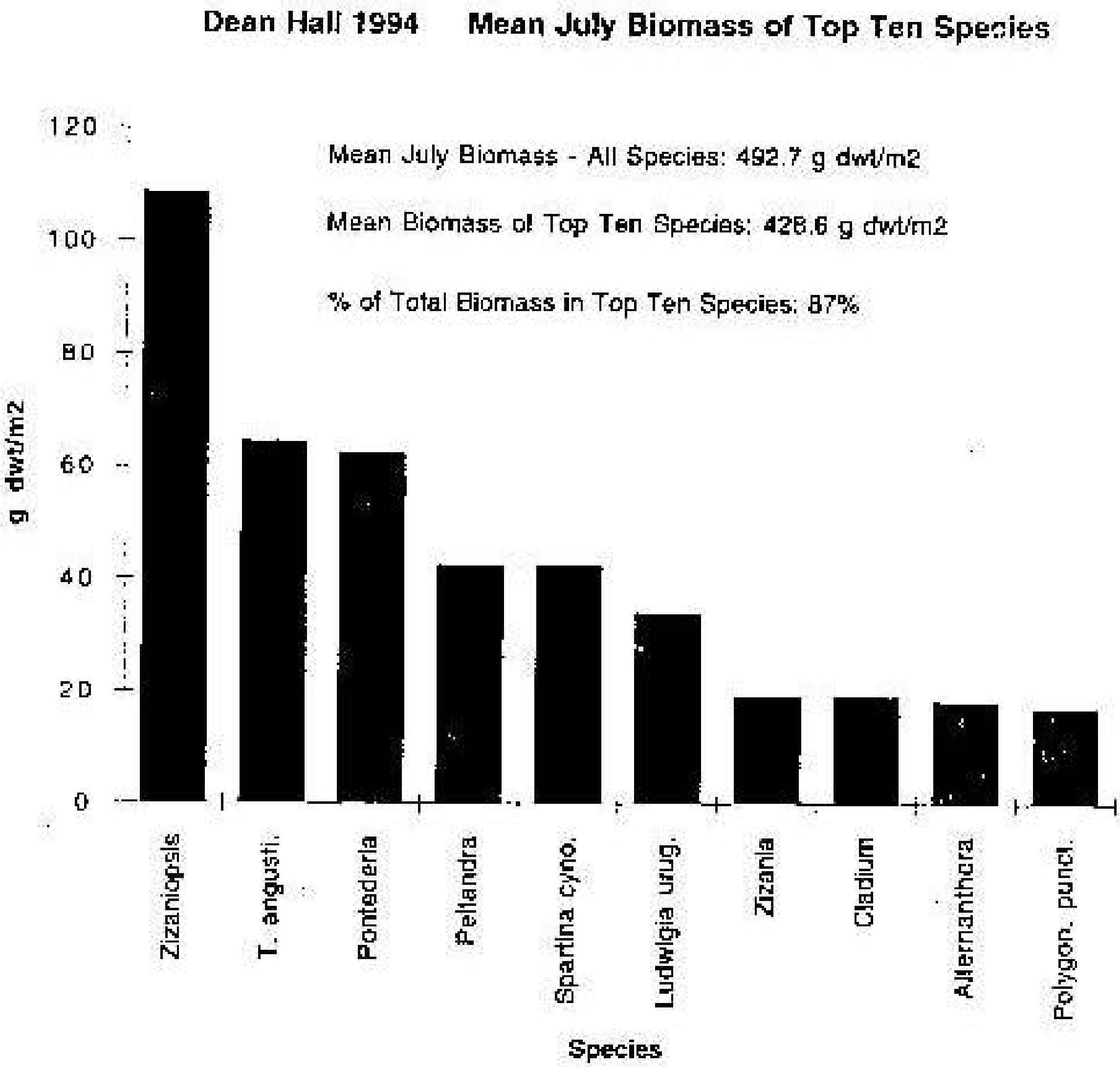


Community	Area(m2)	% Cover
ITEM mix	452392	41
Ludwigia	18006	1.6
Subt Submergent	36812	3.3

by the combination of a hard frost and a high tide aerial photograph. A hard frost kills the above water portions of the plant leaving the submerged portions untouched. Also the detection of Ludwigia in winter aerial photography is affected strongly by tide stage. As high tide water fills ditches and low spots in inter-ditch areas where Ludwigia is found, image recognition sets for water classify the areas as water rather than Ludwigia. A low Ludwigia % cover estimate is produced while on the ground sampling indicates a wider distribution of the species.

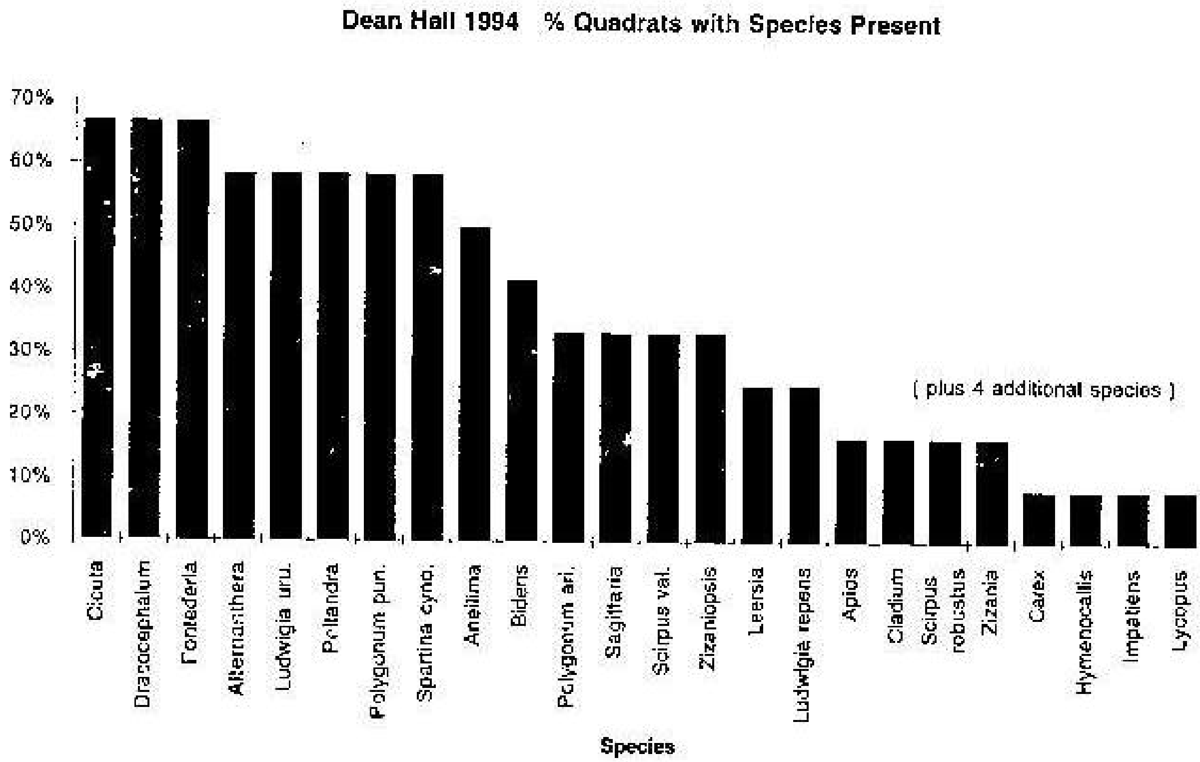
The expansion of the more complex ITEM community appears to be clear in both the 1994 classification figure and in the 1994 frequency/biomass data.

Fig. 11



Dean Hall 1994 Mean July Biomass of Top Ten Species
Mean July Biomass - All Species: 492.7 g dwt/m2
Mean Biomass of Top Ten Species: 428.6 g dwt/m2
% of Total Biomass in Top Ten Species: 87%
g dwt/m2
120
100
80
60
40
20
0
Zizaniopsis
T. angusti.
Pontederia
Peltandra
Spartina cyno.
Ludwigia urug.
Zizania
Cladium
Alternanthera
Polygon. punct.
Species

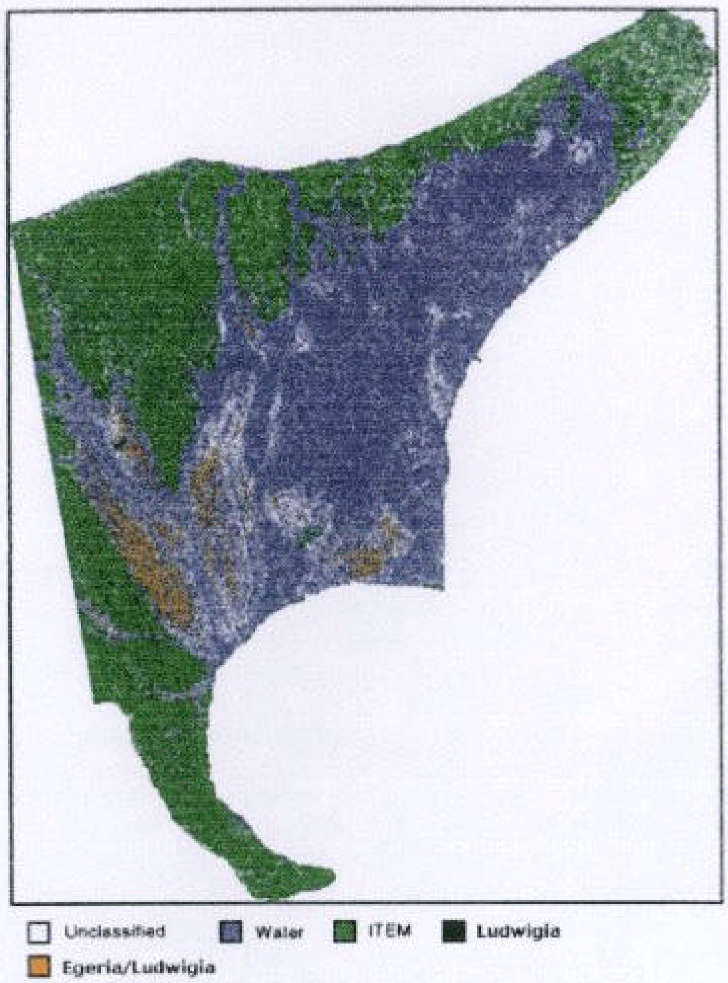
Fig. 12



Dean Hall #2

Dean Hall#2 is adjacent to Dean Hall (fig. 2), having been part of the same plantation. It was chosen because in the late 1970s it had a large percentage of its total area in open water with submergent macrophytes. In this field, ditches and low spots had no emergent cover nor did much of the inter-ditch flat area. It was considered to represent the youngest successional stage in the Cooper sere. Figures 13 and 14 show community cover in spring 1982 and winter 1994. The seasonal differences in the two photographs available make comparison of the two classifications difficult. Ludwigia was not recorded in quadrats in 1982 (fig.15) and 1988 (fig. 16) but was observed to be present in scattered patterns especially among beds of Egeria. During the 1982 - 1994 study period, it increased from a scattered presence in 1982 and 1988 to a biomass dominant in 1995 (figs. 17, 18 & 20). The presence of Ludwigia in quadrats (Fig. 19) in 1994 and as a recognizable classification set in 1994 is an indication of an important successional step in the Dean Hall #2 field. Further, the actual distribution of Ludwigia in

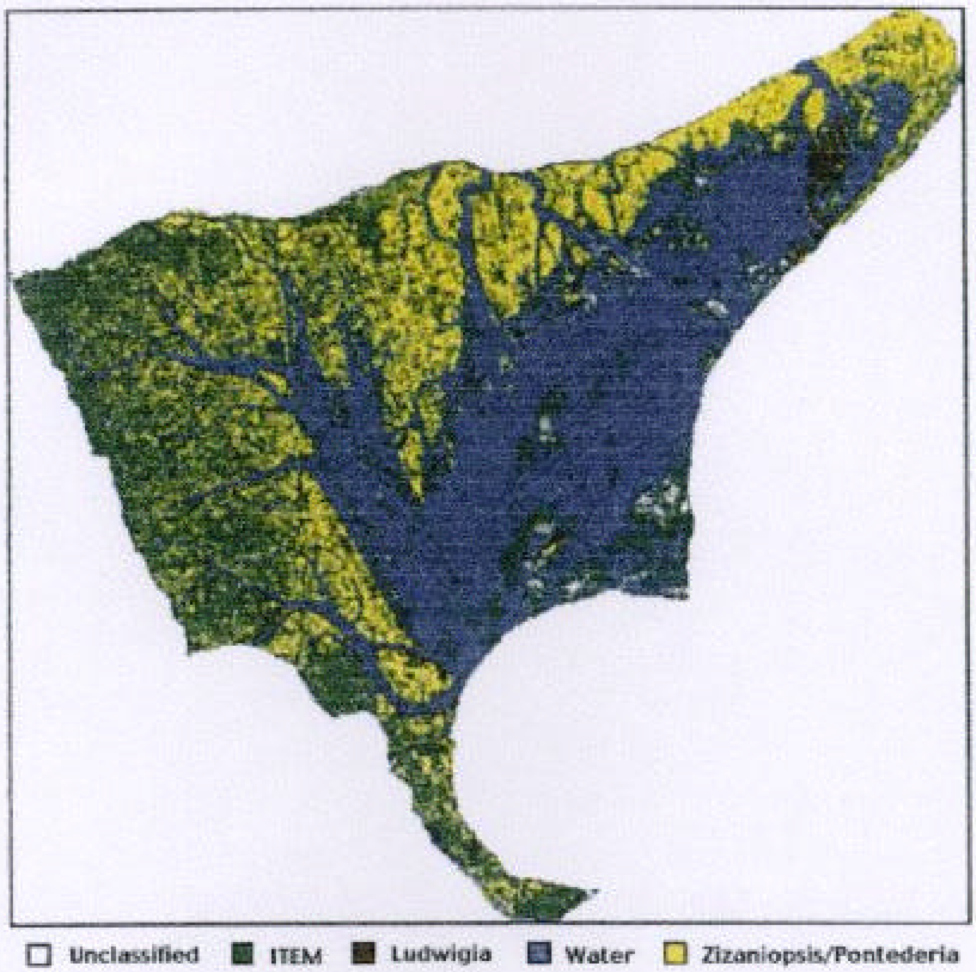
Fig. 13 Dean Hall # 2 Spring 1982



Community	Area (m2)	% Cover
Egeria/Ludwigia	270198	10.1
ITEM mix	261279	9.8
Pontederia/Zizaniopsis	164387	6.1

the open water areas of Dean Hall #2 in 1994 is far greater than the winter photography shows (see color slides taken in the fall of 1994 and 1995 before freezes which kill above

Fig. 14 Dean Hall #2 Winter 1994



Community	Area (m2)	% Cover
Ludwigia	51423	1.6
ITEM mix	473788	14.6
Zizaniopsis/Pontederia	299972	9.2

the water portions of the plant). In the Cooper system, the transition between open water with submergents to rooted emergents seems to be accomplished primarily by Ludwigia uruguayensis. Eichornia (water hyacinth) has recently, since 1988, become another factor in the closing of open water in the Cooper. Although it is not rooted, it becomes trapped in Ludwigia mats and often appears in the same position over time. The apparent differences in emergent species in inter-ditch areas seen in Figures 13 & 14 may be due

to seasonal differences in the same communities. Comparison of summer data from 1982 (fig.17) and 1995 (figs. 20) suggested little change in species composition or biomass distribution in inter-ditch emergent communities over the period. Lycopus, prominent in frequency and biomass in 1982, seems to be losing importance in 1994 (fig. 20), as it did in similar areas in Dean Hall during the same period).

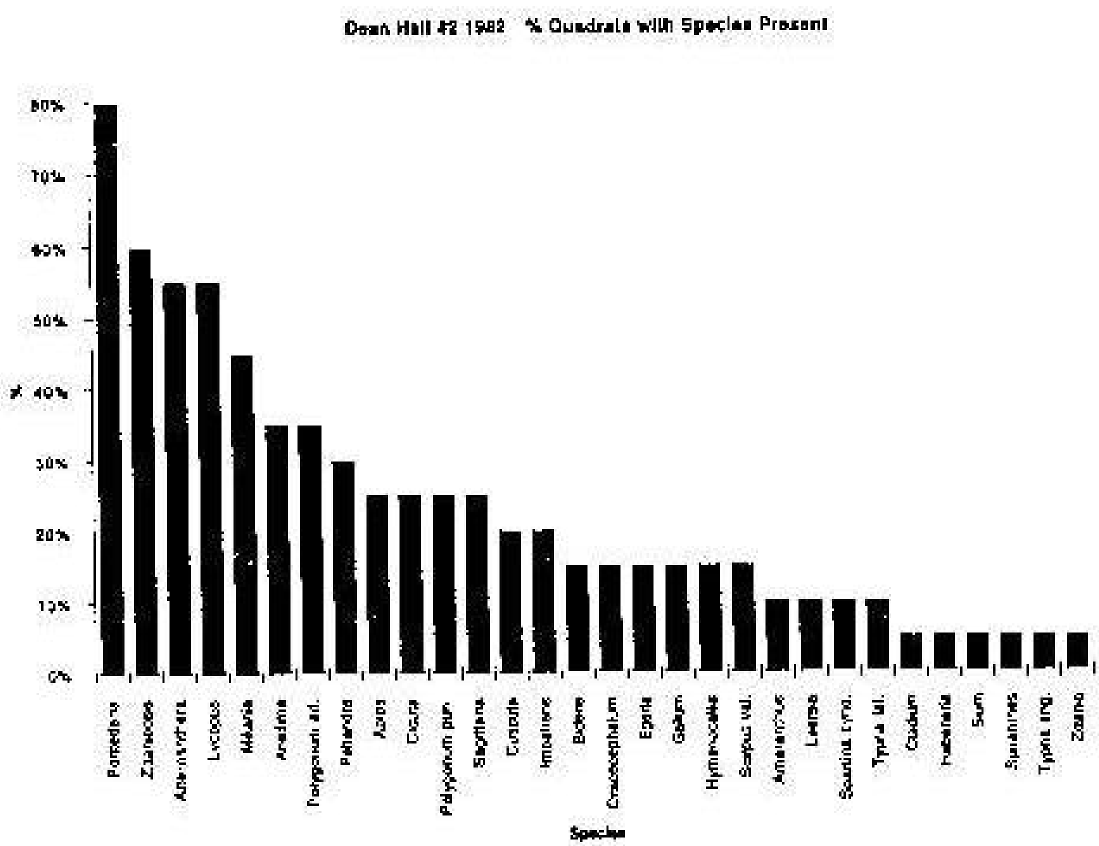
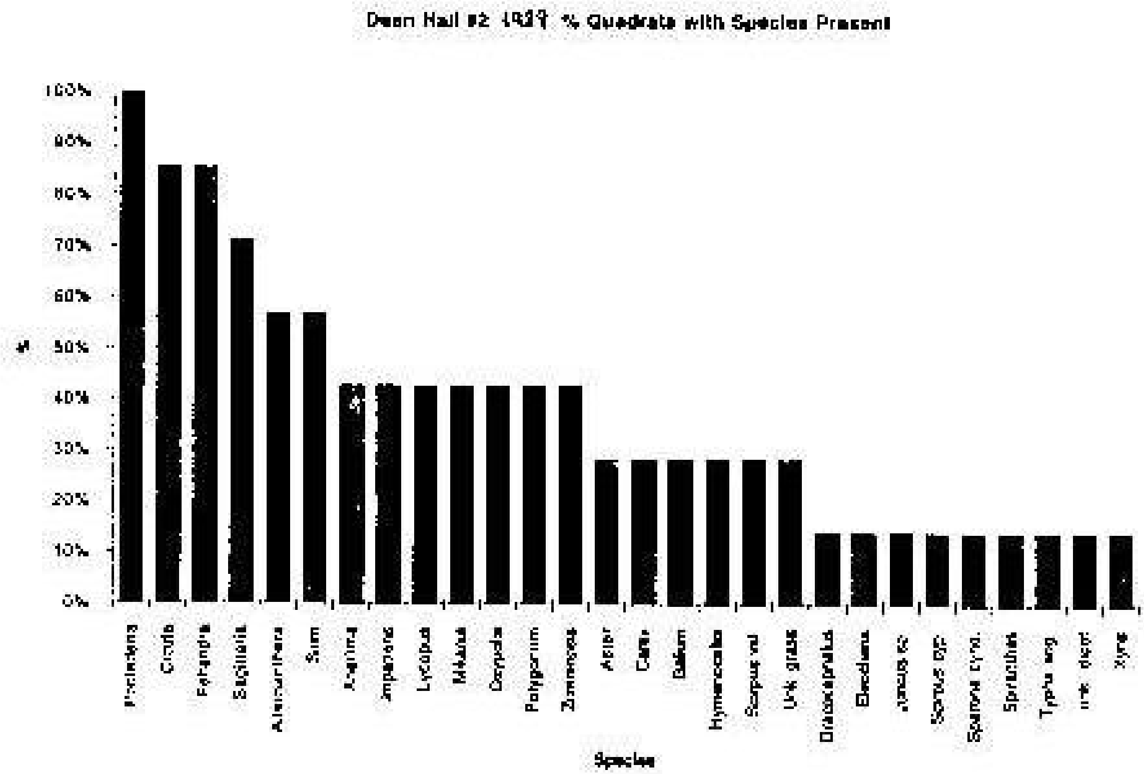


Figure 15

Fig. 16



Dean Hall #2 1929 % Quadrats with Species Present
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cicuta
Sagittaria
Sium
Lycopus
Polygonum
Aster
Carex
Galium
Hymenocallis
Unk grass
Eleocharis
Spartina cyno.
Typha ang
Xyris
Species

Fig. 17

Dean Hall #2   Mean July Biomass of Top Ten Species - 1992

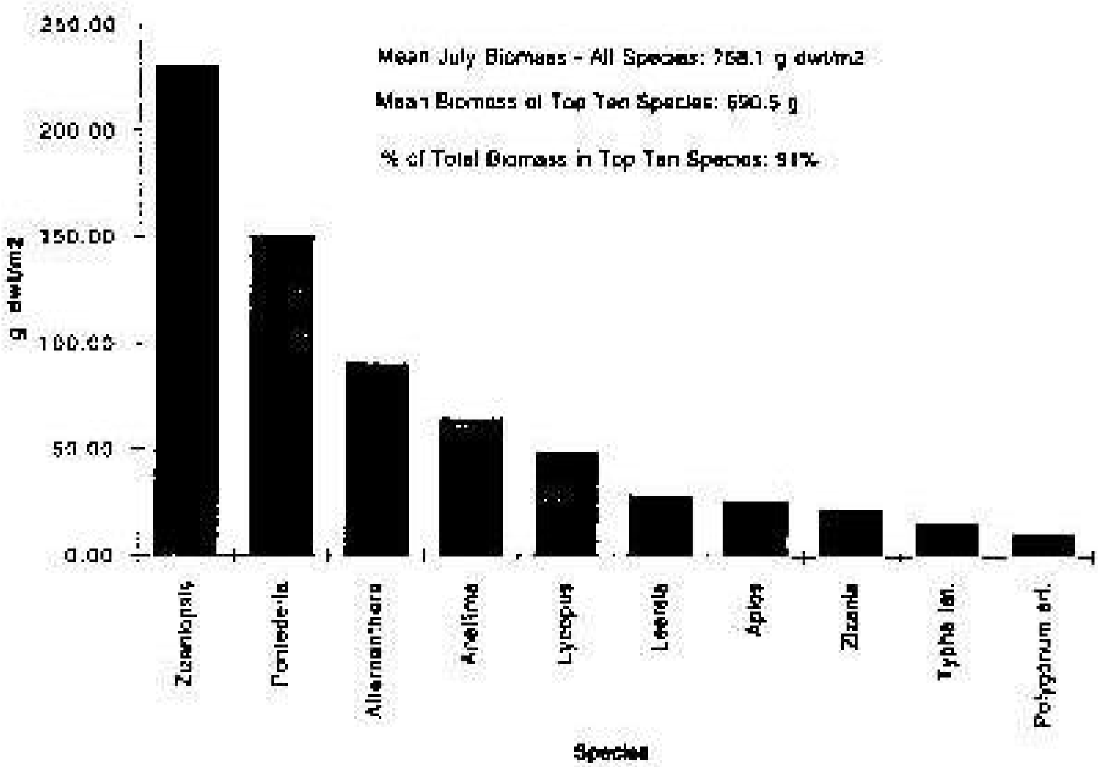


Fig. 18

Dean Hall #2 1989 Mean March Biomass of Top Ten Species

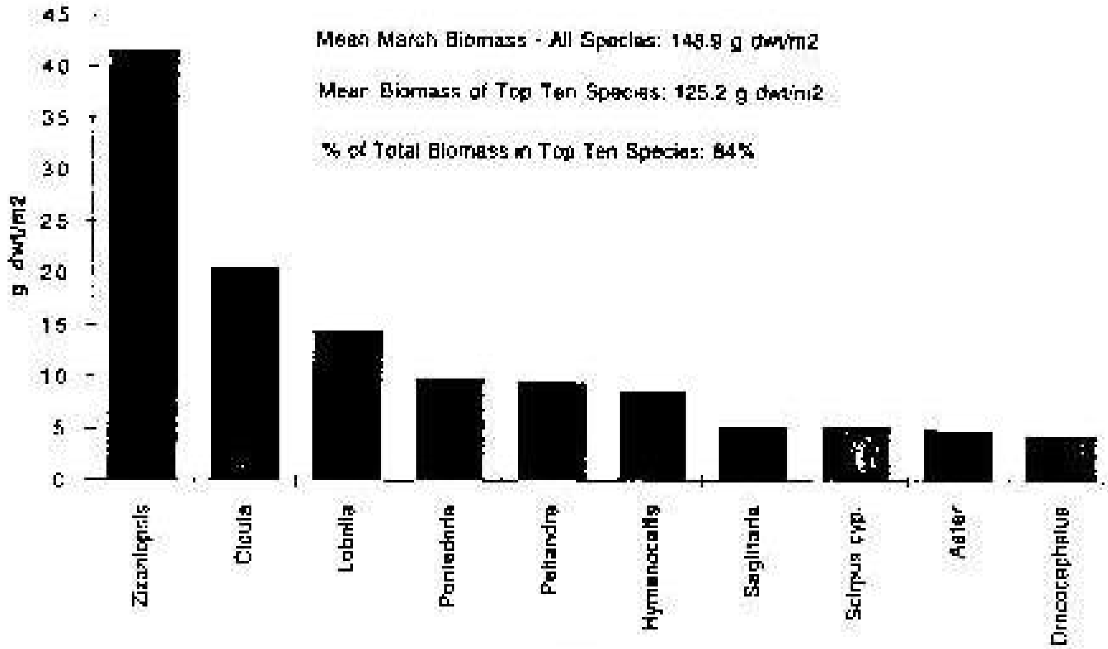


Fig. 19

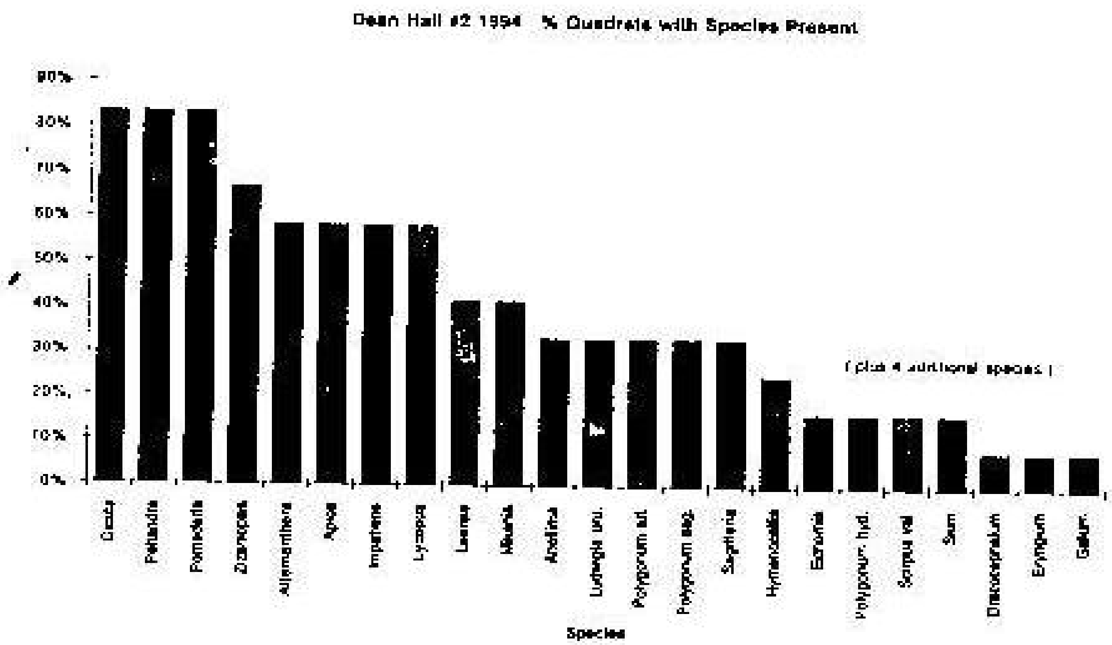
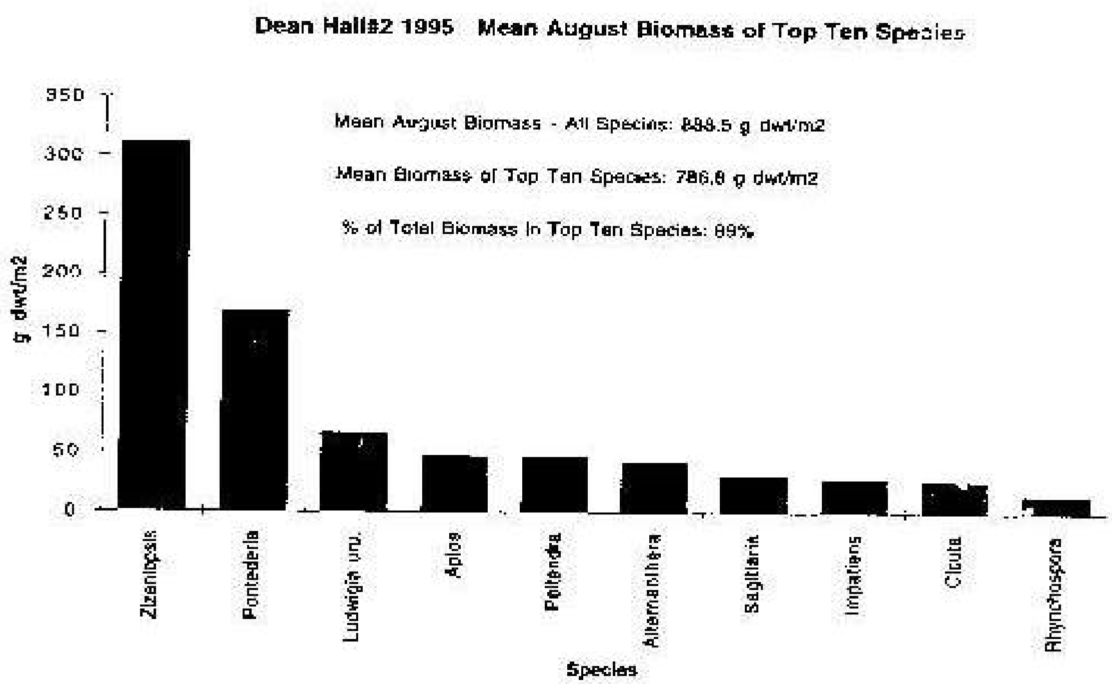

Dean Hall #2 1994 % Quadrats with Species Present
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
(plus 4 additional species)
Peltandra
Pontederia
Alternanthera
Impatiens
Ludwigia uru.
Sagittaria
Polygonum hyd.
Scirpus val
Eryngium
Galium
Species

Fig. 20


Dean Hall#2 1995 Mean August Biomass of Top Ten Species
Mean August Biomass - All Species: 888.5 g dwt/m2
Mean Biomass of Top Ten Species: 786.8 g dwt/m2
% of Total Biomass in Top Ten Species: 89%
g dwt/m2
350
300
250
200
150
100
50
0
Zizaniopsis
Pontederia
Ludwigia uru.
Apios
Peltandra
Alternanthera
Sagittaria
Impatiens
Cicuta
Rhynchospora
Species

Quinby

An especially high quality, low level 1977 aerial photo allowed us to get a good level of resolution in our Quinby classification shown in Figure 21. In 1977 Quinby had almost complete cover with emergent intertidal communities. We chose Quinby to represent a more advanced successional stage than Dean Hall but one still dominated by grasses and sedges. Most interior ditches were blocked with Ludwigia, closing the interior to boat traffic. A few scattered trees; e.g., Acer rubrum, not more than 3 feet tall, were present. The distribution of emergent communities in relation to elevation is apparent in Figure 21. Lowest areas in ditches support Ludwigia. Moving up ditch banks, Pontederia and Cicuta. Next higher Pontederia/Scirpus americanus followed by a switch in proportions to S. americanus/Pontederia. Most of the inter-ditch area at Quinby was occupied by S. americanus/Aneilma. In some slightly higher areas there were patches of

Fig. 21 Quinby Winter 1977

Community	Area (m2)	% Cover
Cladium	4328	2.6
Ludwigia	9745	5.8
Pontederia/Cicuta	19741	11.7
Pontederia/S. amer.	5991	3.6
S. amer./Aneilima	63083	37.5
S. amer./Pontederia	16957	10.1
S. cyno./Kosteletskya	8412	5
Tree	5858	3.4

Spartina cynosuroides /Kosteletskya. Compared to Dean Hall and Dean Hall #2, 1982 Quinby ground data shows species abundance was high (figs. 22 & 23). Concentration of biomass in the top ten species (fig. 24) is not as high at Quinby as at Dean Hall and Dean Hall#2.

Fig. 22

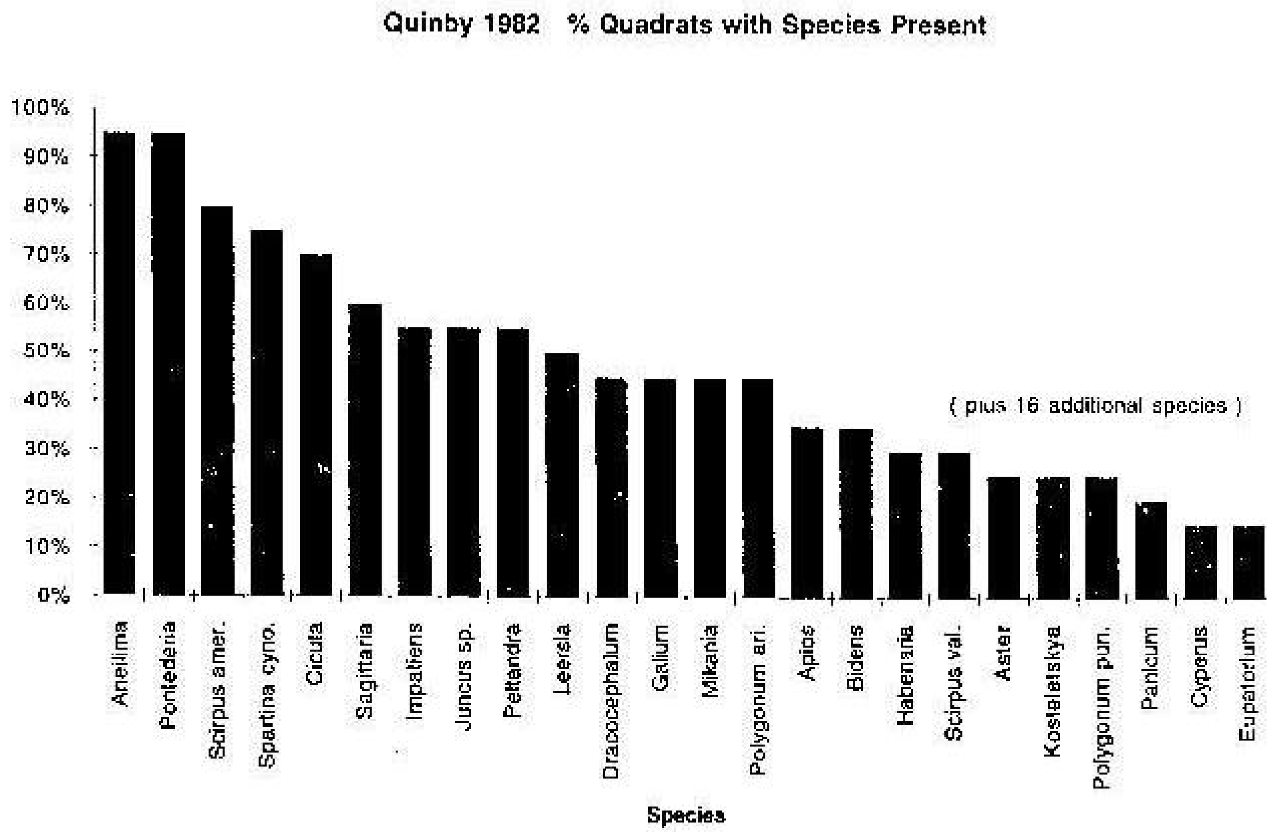
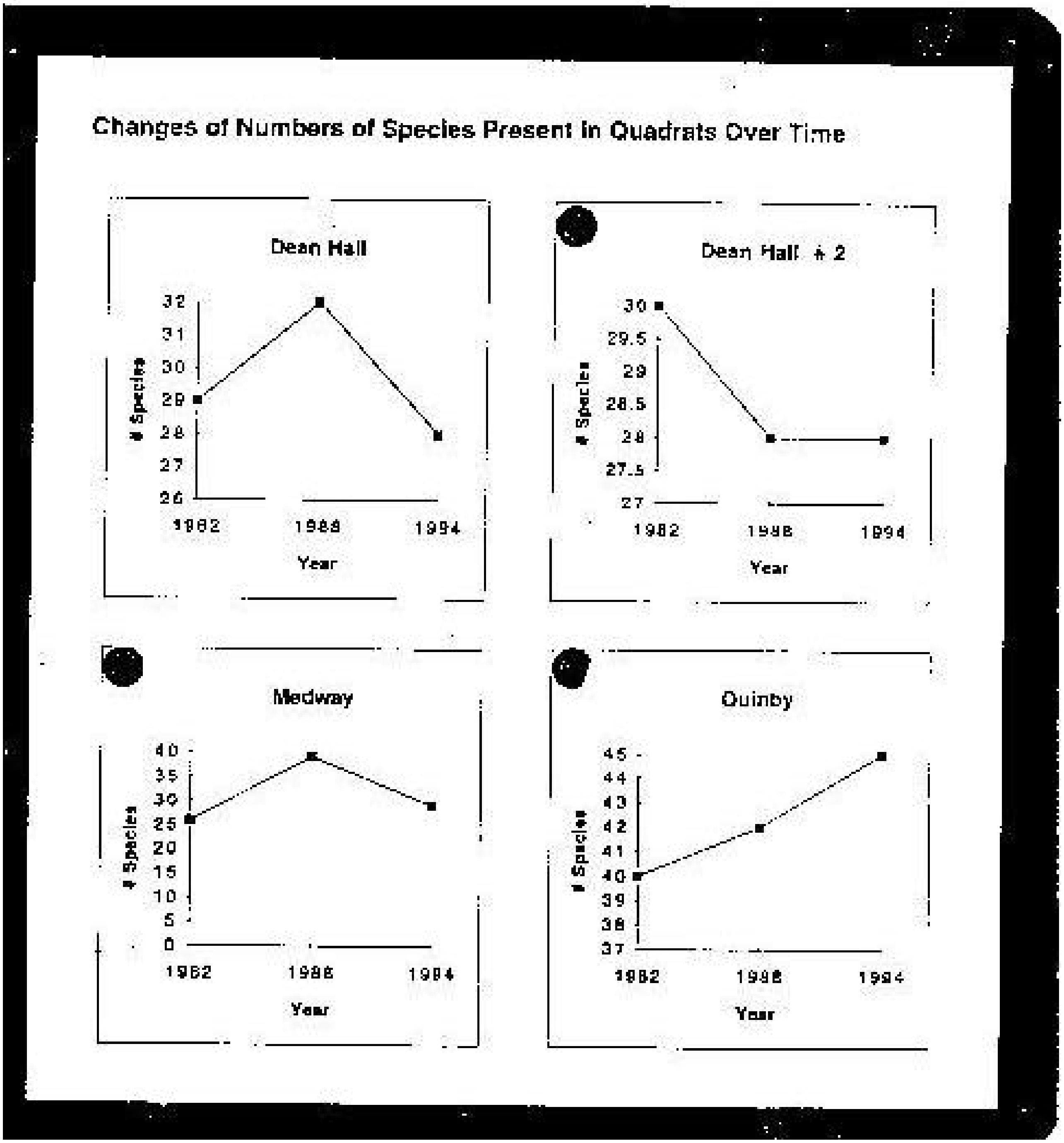
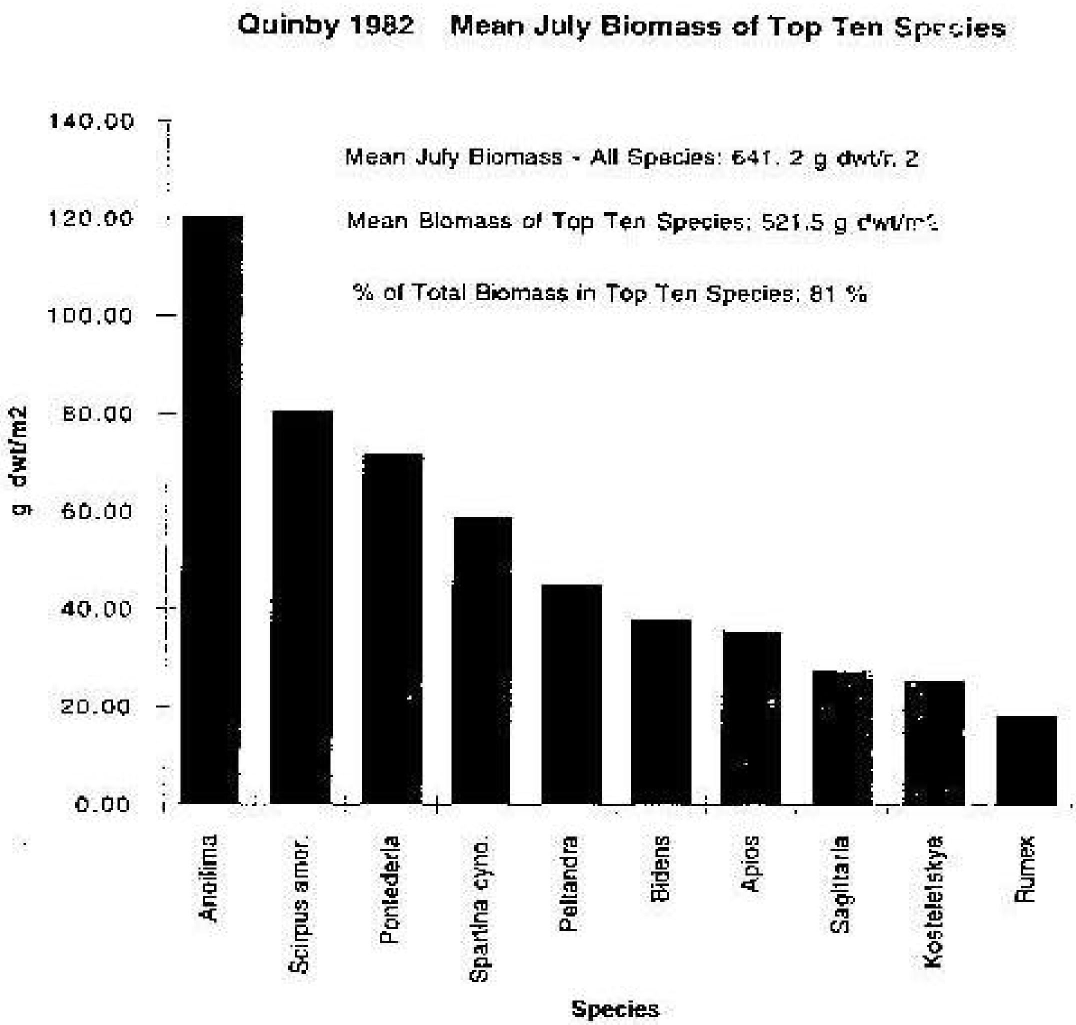


Fig. 23



Changes of Numbers of Species Present in Quadrats Over Time
Dean Hall
32
31
30
29
28
27
26
Species
1982
1988
1994
Year
Dean Hall # 2
30
29.5
29
28.5
28
27.5
27
Species
1982
1988
1994
Year
Medway
40
35
30
25
20
15
10
5
0
Species
1982
1988
1994
Year
Quinby
45
44
43
42
41
40
39
38
37
Species
1982
1988
1994
Year

Fig. 24



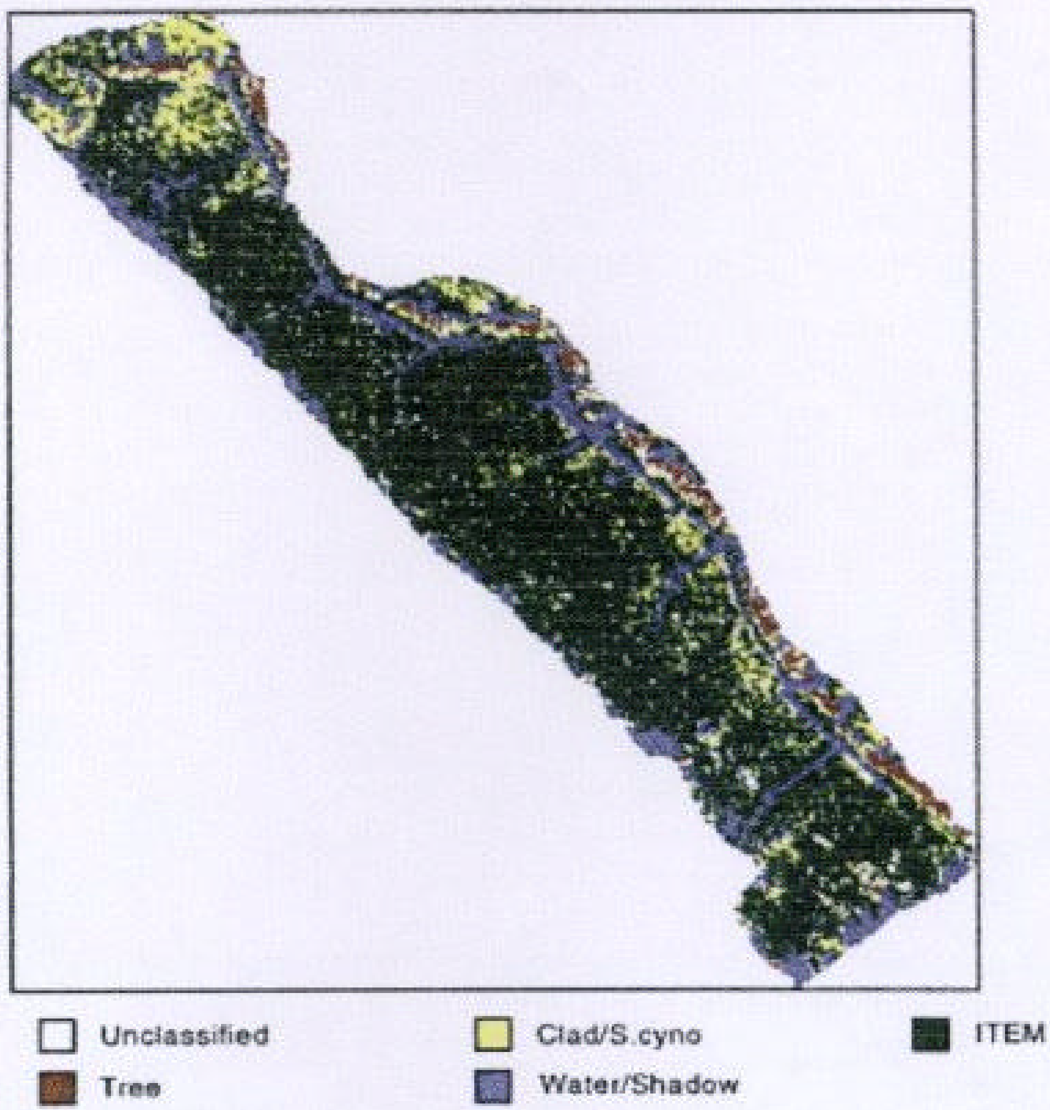
The spring 1982 classification (fig. 25) shows that Ludwigia is confined largely to ditches and that broad leaf perennials, Pontederia and Cicuta, dominate in spring as they do in lower successional stages. Summer 1982 species frequency and biomass data show differences in dominant species as compared to Dean Hall and intertidal portions of Dean Hall #2: notably the absence of Zizaniopsis and the greater importance of Aneilima and Spartina cynosuroides.

Fig. 25 Quinby Spring 1982

Community	Area(m2)	% Cover
Ludwigia	10760	5.9
Pontederia/Cicuta	39027	21.3
Pontederia/S. amer.	93054	50.8

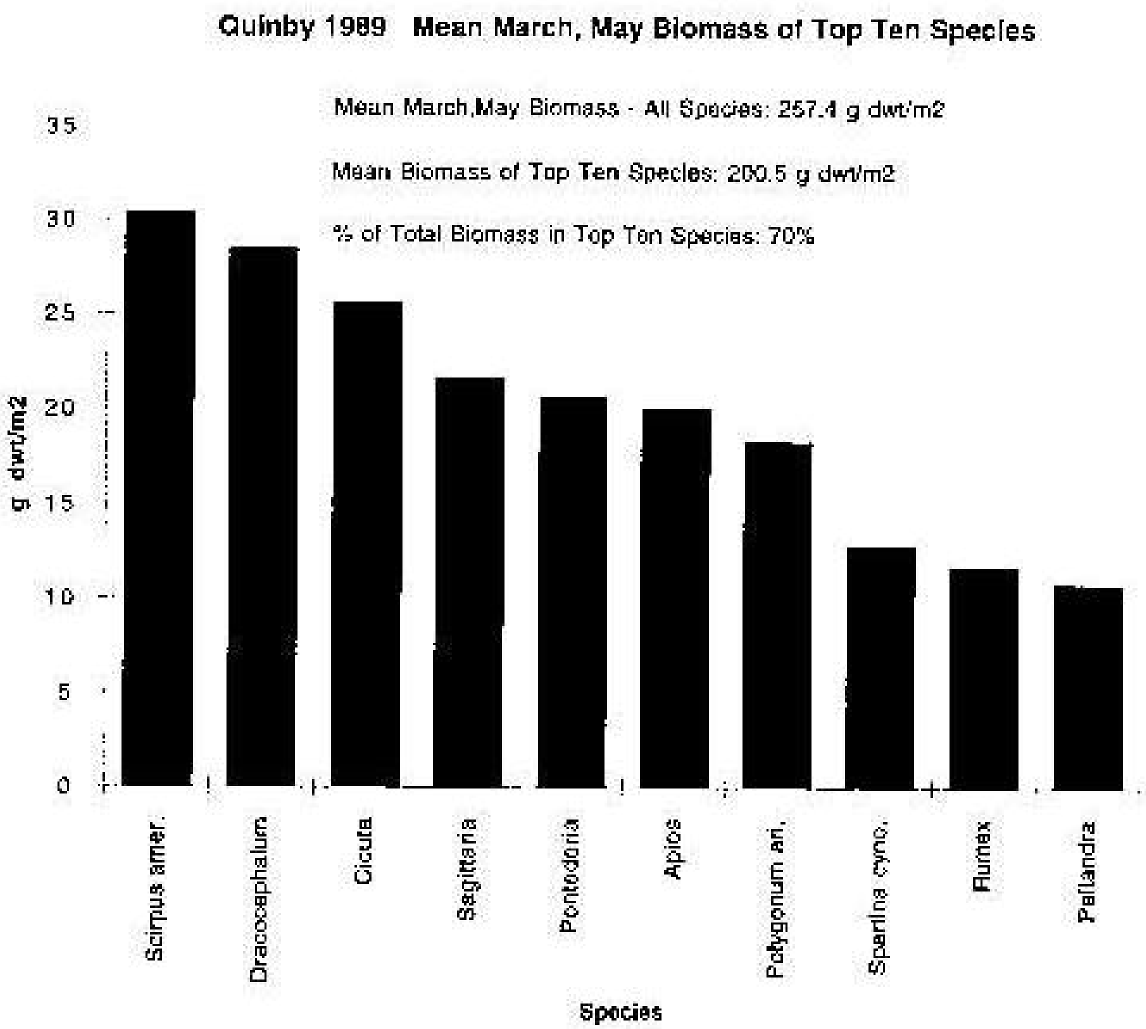
By 1989 the S. americana/Pontederia had expanded to 34.5% (fig. 26) and tree cover to 17.3%. Trees that were less than 3 feet in 1977 had in some cases exceeded 10 feet. Species abundance remained high (figs. 23 & 27) and biomass was less concentrated in the top ten species (fig. 28).

Fig. 26 Quinby Winter 1989



Community	Area(m2)	% Cover
Cladium/S. cyno.	14345	7.8
ITEM	81390	44.5
Tree	31743	17.3

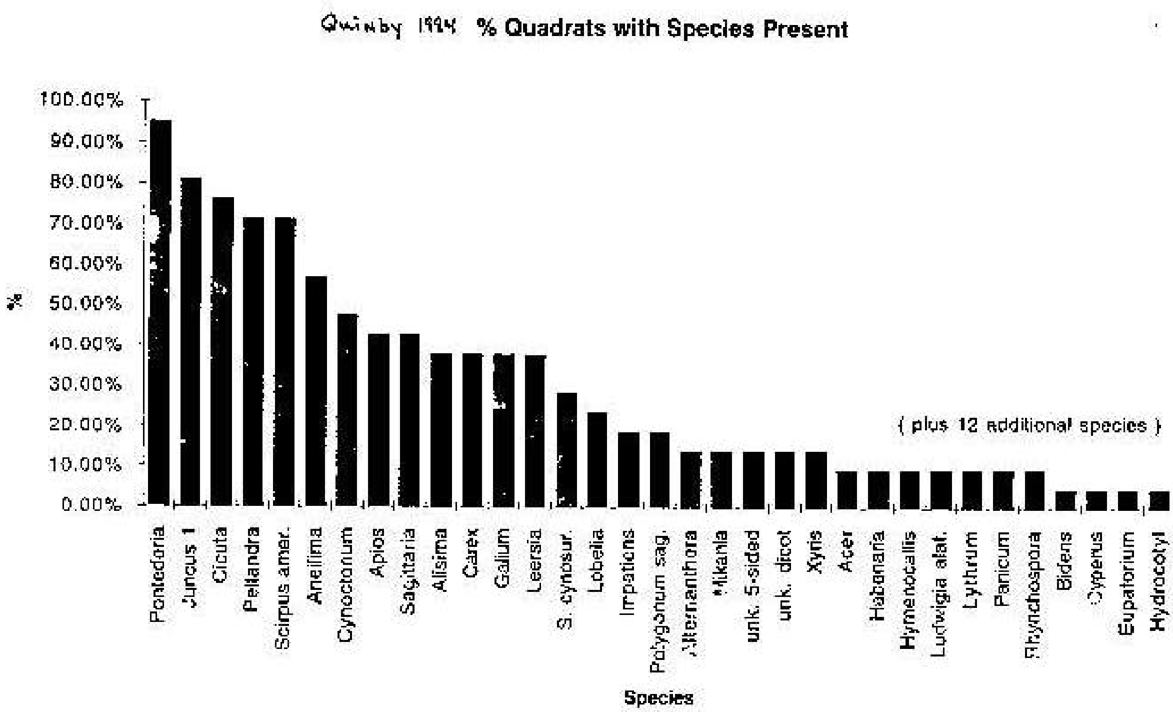
Figure 27



1994 color IR photography was of poor quality and didn't allow classification. 1994 ground data (figs. 28, 29 & 30) and oblique color slide photography showed the persistence of the S. americana dominated inter-ditch areas and clear increase in tree cover in the southwestern end of the field. Species abundance was high and the field had the appearance of a terrestrial old field even though soils remained saturated at all tides in 1994. On the ground observation and low level color slide photography show numerous deer, rabbit and other small animal trials throughout the S. americana dominated areas of the field. These trails are not evident in the intertidal areas of Dean Hall and Dean

Hall#2.

Fig. 28



Medway

In 1977 we chose Medway to represent advanced successional stages since numerous small trees were present, scattered throughout the field. At Medway these were predominately willows (Salix sp.) and red maples (Acer rubrum) although other late stage Cooper fields sometimes contained sea myrtle (Baccharis), wax myrtle (Myrica) and pond gum (Nyssa). Medway was different from the other three fields we followed in that large, deep interior ditches had been overgrown by Typha which formed thick rootmats that other plants, including trees, used as soil. Almost any transect leading from the river to high land passes across one these areas, which bounce and shake as they are crossed. A paddle pushed into the rootmat breaks through to water after penetrating 12 -18 inches. Other such situations are common along the Cooper system and create a side branch in the succession pattern typical of flatter areas.

Fig. 29

Quinby 1994 Mean April, March Biomass of Top Ten Species

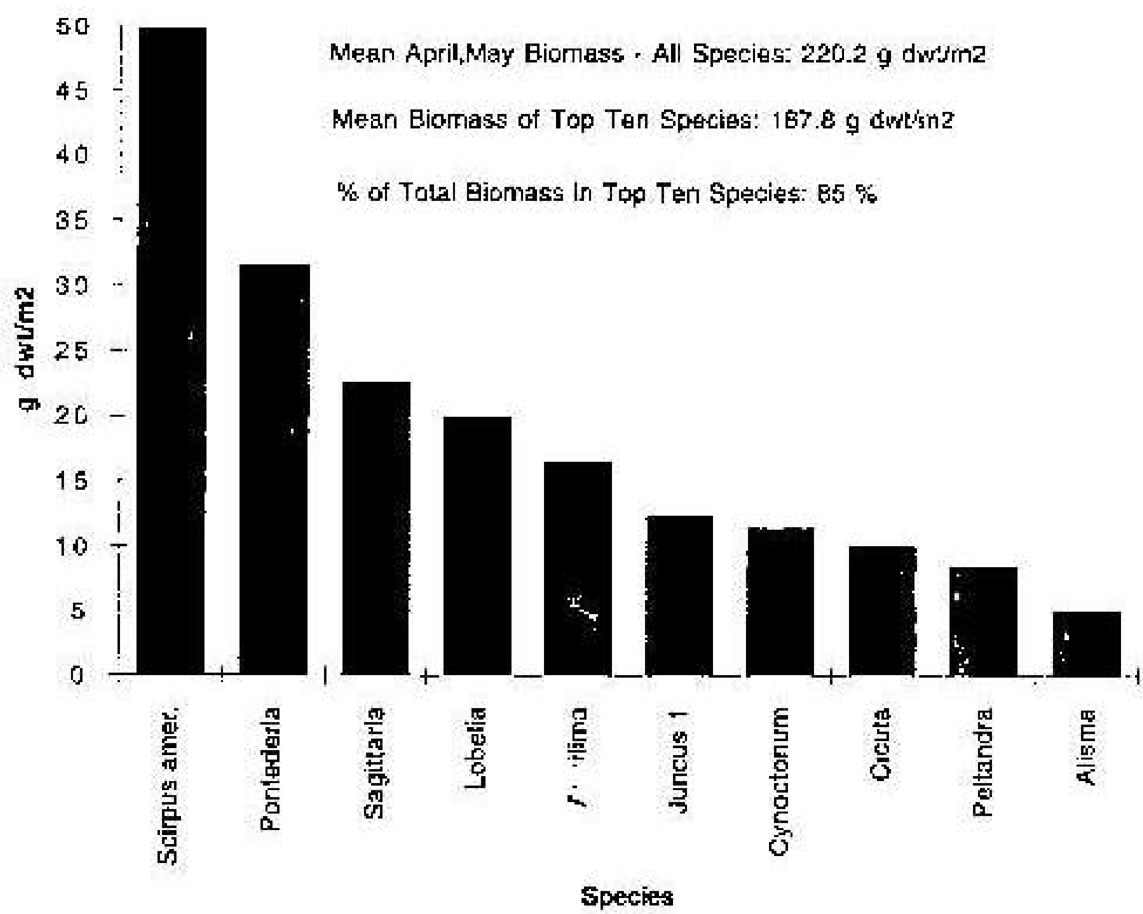
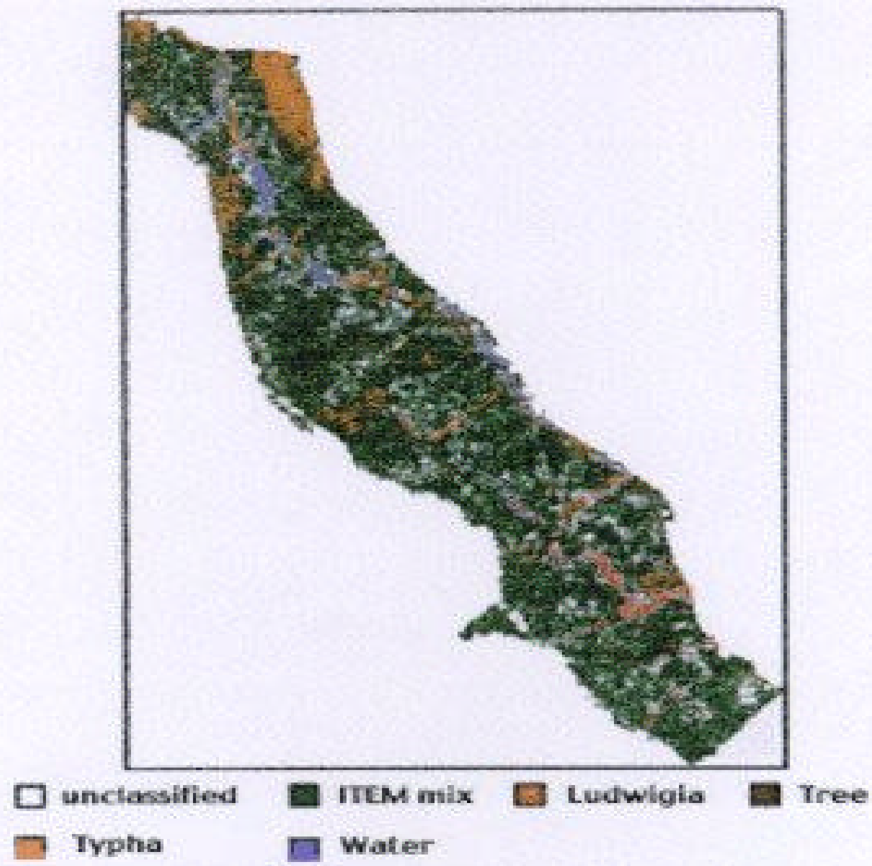


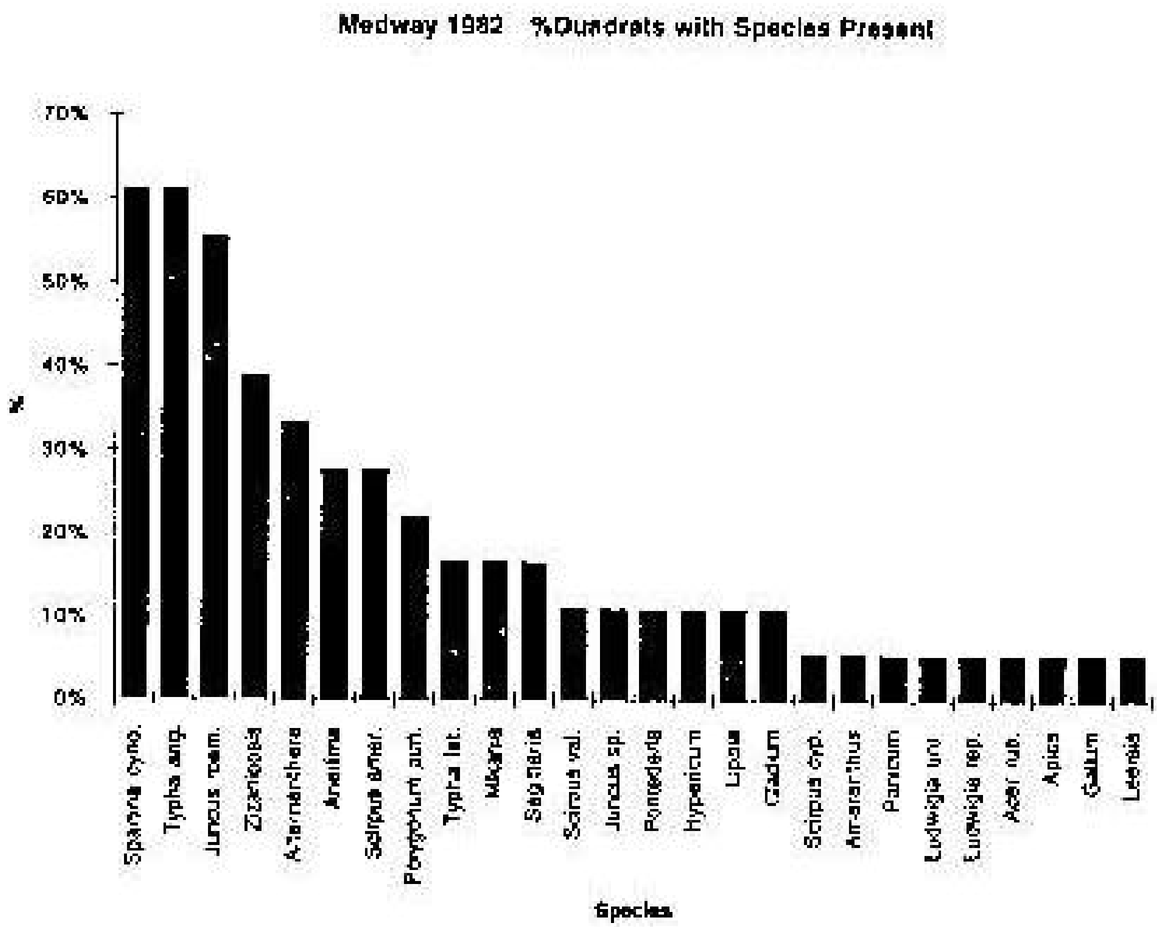
Fig. 30 Medway Winter 1977



Community	Area(m2)	% Cover
ITEM mix	73930	17.6
Ludwigia	2199	.5
Typha	15321	3.6
Tree	291	.05

Figure 31 is a classification of Medway from 1977 aerial photography using field maps and notes as verifiers. Open water, Typha and Ludwigia covered areas have become the quaking earth areas mentioned above. Although trees were widely present, they were small and scattered making them hard to detected in the aerial photography. The predominant cover was an ITEM community with many of the same species found in the Dean Hall and Dean Hall #2 ITEM community but with different dominants; e.g., more Spartina cynosuroides and Typha angustifolia.

Fig. 31



1982 photography was unavailable and July 1982 ground data (figs. 32 & 33) shows little change since 1977. 1989 spring ground data (figs. 34 & 35) show a field dominated by tall grasses and low understory instead of broad leaf perennials as in Dean Hall, Dean Hall #2 and Quinby.

Pontederia, a strong dominant in the other three fields is present but rare at Medway.

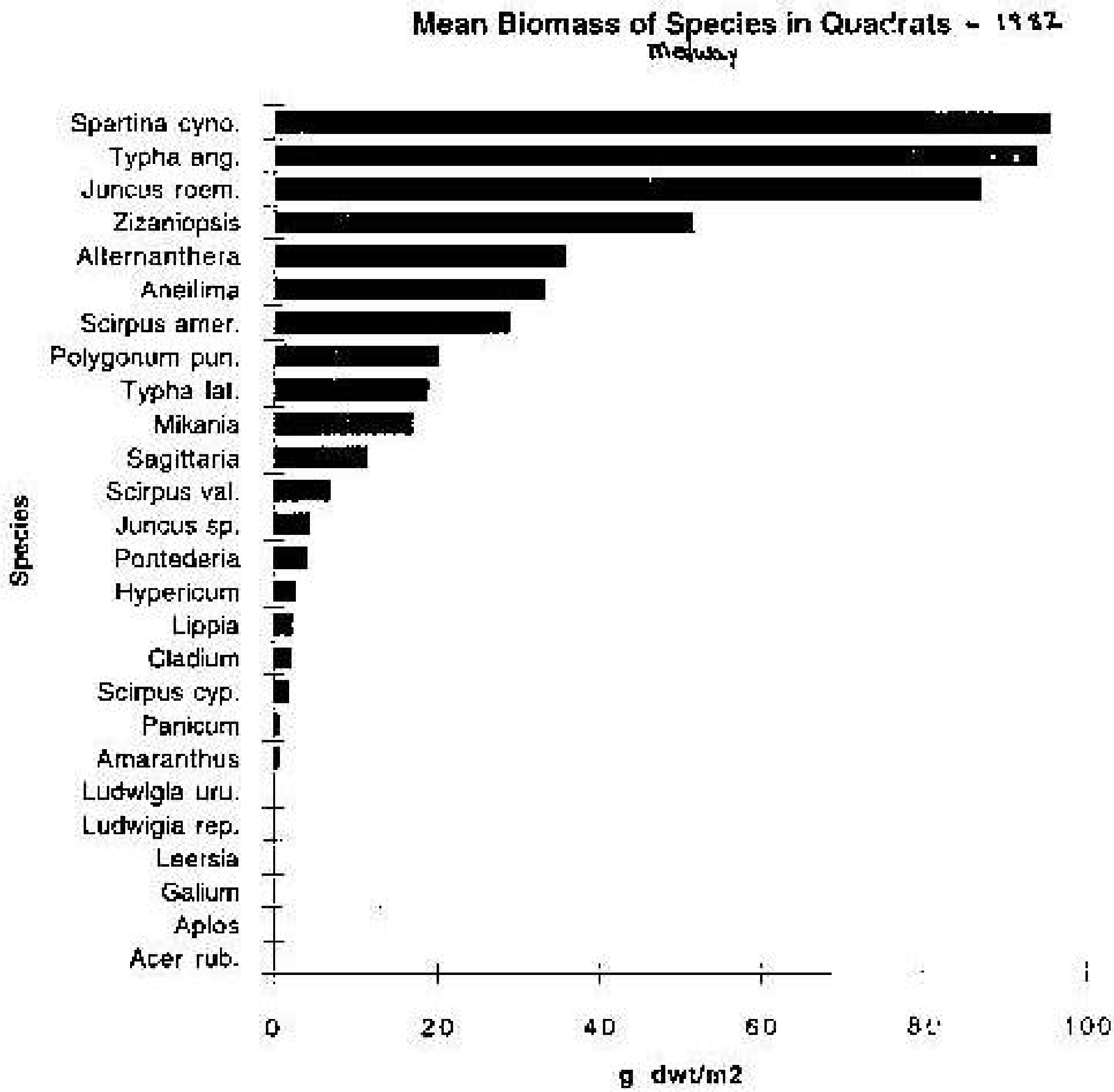
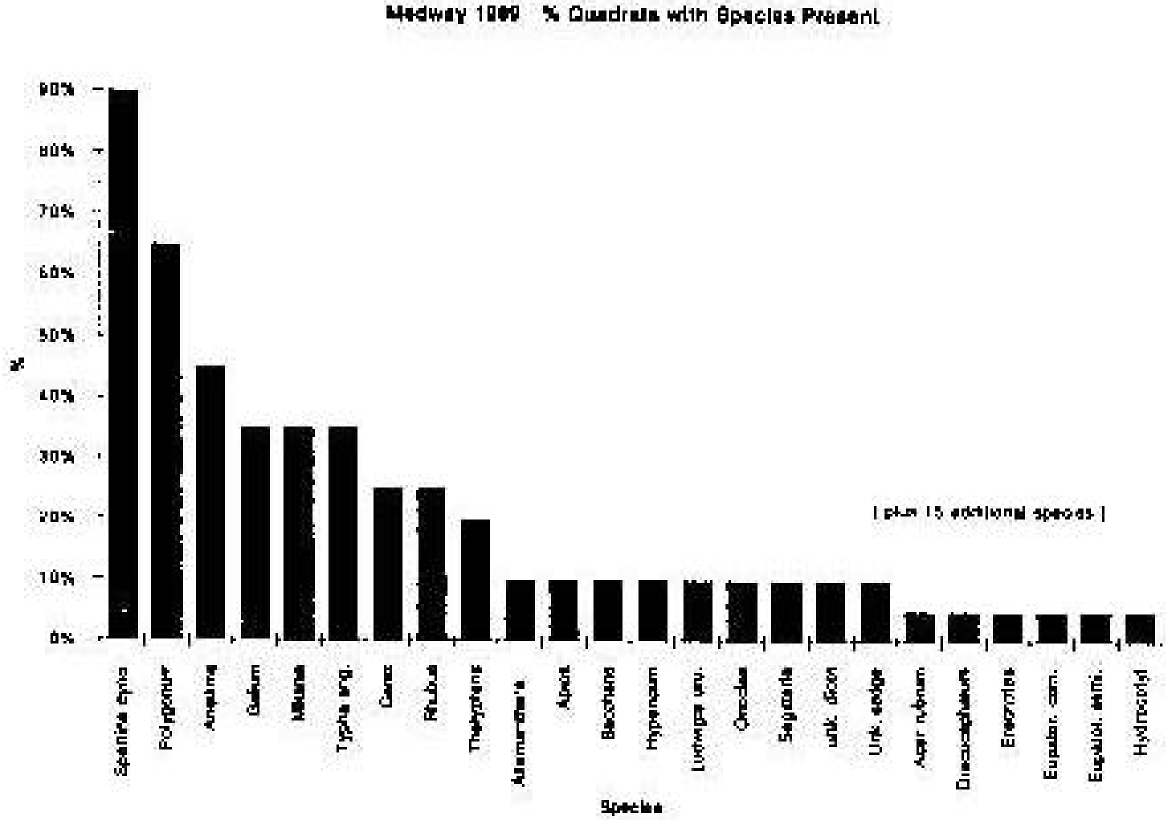


Figure 32

Fig. 33


Medway % Quadrats with Species Present
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
%
(plus 15 additional species)
Spartina cyno
Polygonum
Galium
Mikania
Typha ang.
Carex
Rubus
Thelypteris
Alternanthera
Apios
Baccharis
Hypericum
Ludwigia uw.
Onoclea
Sagittaria
unk. dicot
Unk. sedge
Acer rubrum
Erechtites
Eupator. cann.
Eupator. semi.
Hydrocotyl
Species

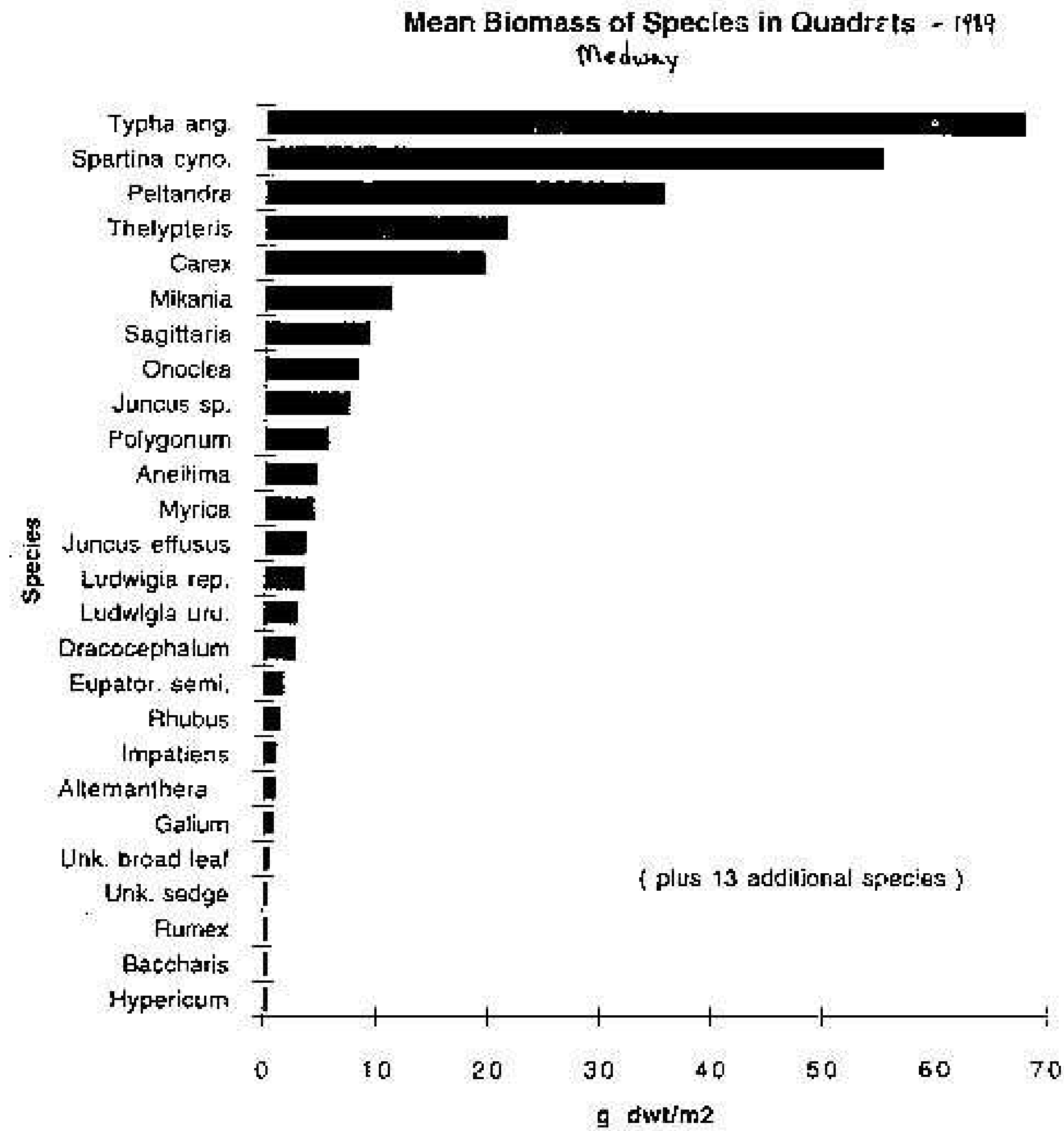

Mean Biomass of Species in Quadrats - 1989
Medway
Typha ang.
Spartina cyno.
Peltandra
Thelypteris
Carex
Mikania
Sagittaria
Onoclea
Juncus sp.
Polygonum
Aneilima
Myrica
Juncus effusus
Ludwigia rep.
Ludwigia uru.
Dracocephalum
Eupator. semi.
Rhubus
Impatiens
Alternanthera
Galium
Unk. broad leaf
Unk. sedge
Rumex
Baccharis
Hypericum
Species
(plus 13 additional species)
0
10
20
30
40
50
60
70
g dwt/m2

Figure 34

Fig. 36 Medway Winter 1994

Community	Area(m2)	% Cover
ITEM mix	44444	10.2
S. cynosuroides	11879	2.7
Typha/S. cyno.	32227	7.4
Tree	6648	2.0

Figure 36 is a classification from 1994 photography. Photo quality was not good but expansion of tree cover is clear and persistence of the ITEM community continued from the prediversion classification. In the northeastern corner of the field, S. cynosuroides seems to be replacing an almost pure stand of Typha. Floating mats now have sizeable trees and complex mixes of associated species. Oblique slide photos show clearly the increasing dominance of trees, still mostly red maple and swamp willow. Species abundance (figs. 37 & 23) is comparable to Dean Hall and Dean Hall#2 but lower than at Quinby. Biomass is concentrated in the top ten species (fig. 37). We know of few better places to look for cottonmouth moccasins.

Fig. 36

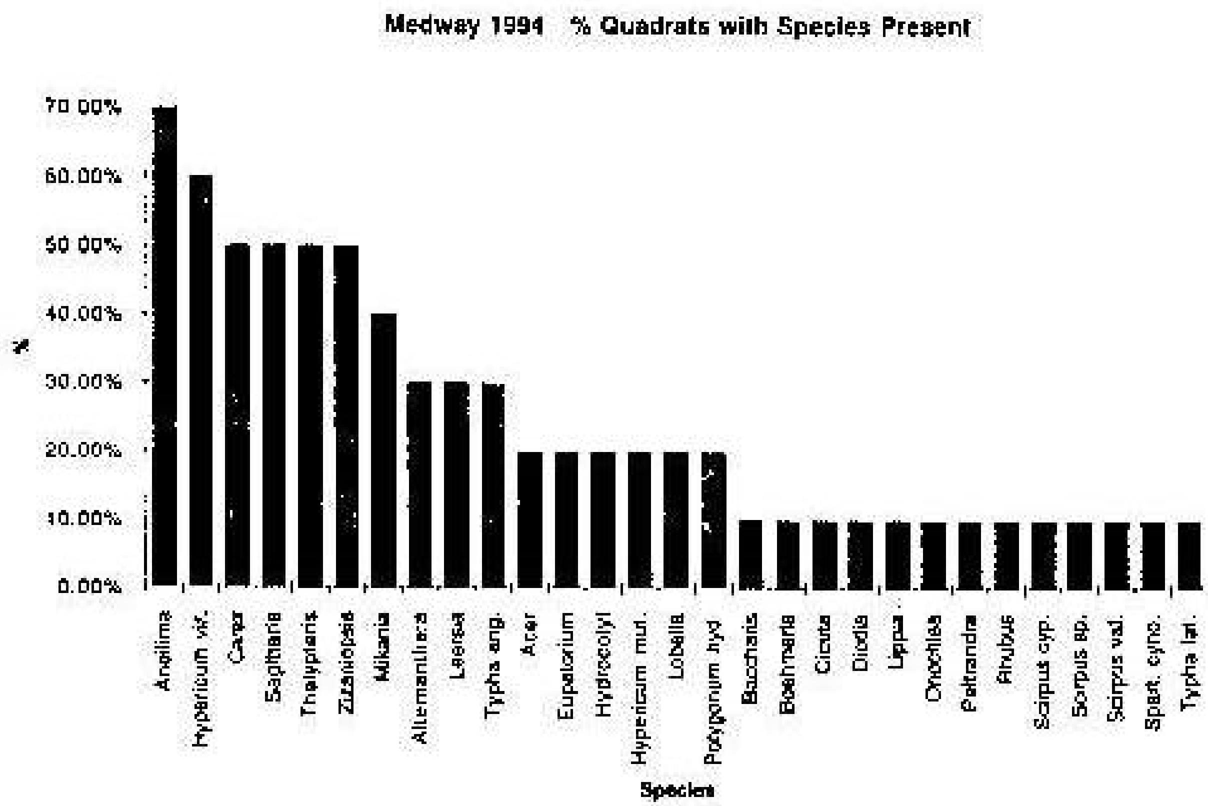


Fig. 37

Medway 1994

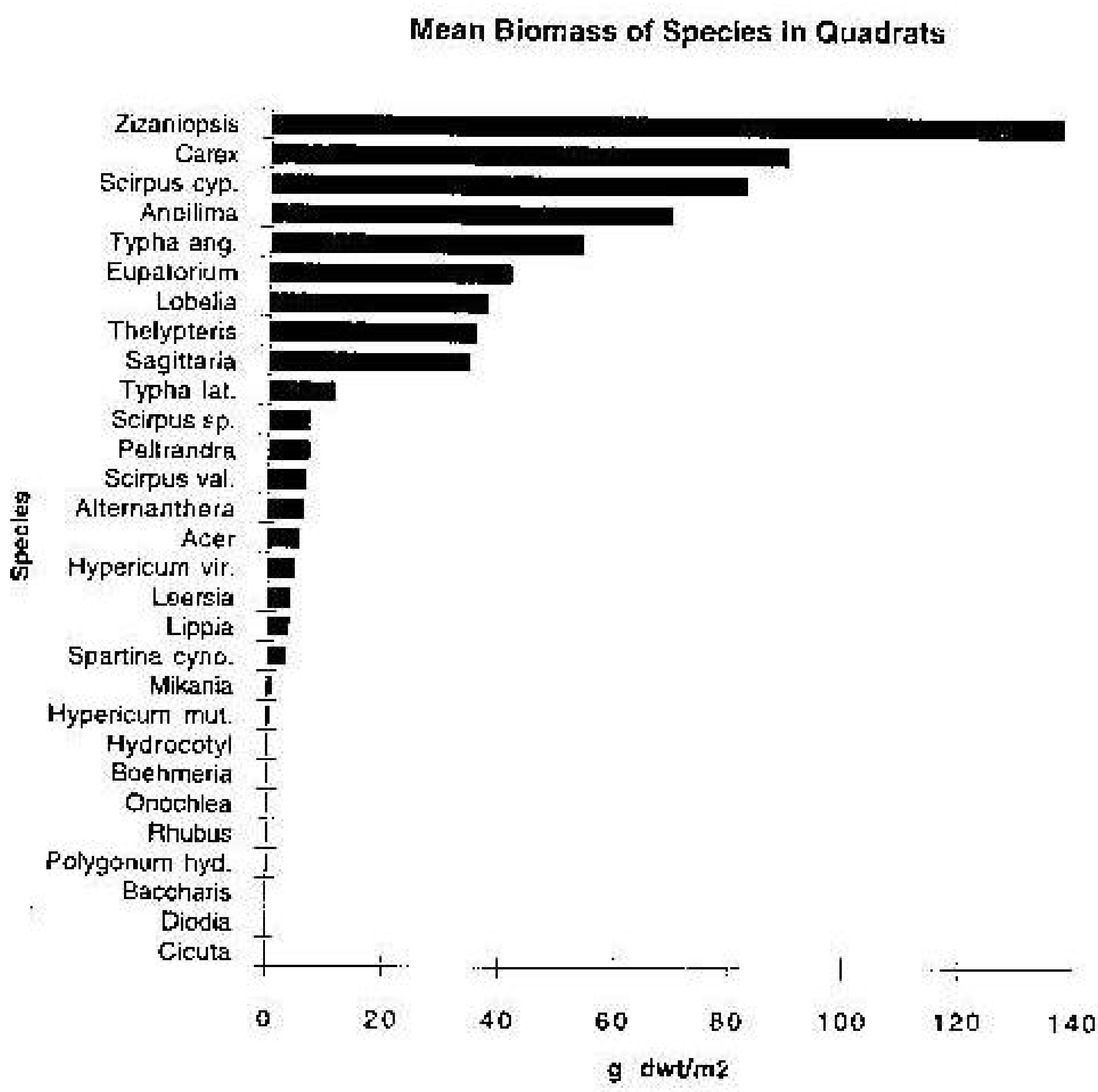
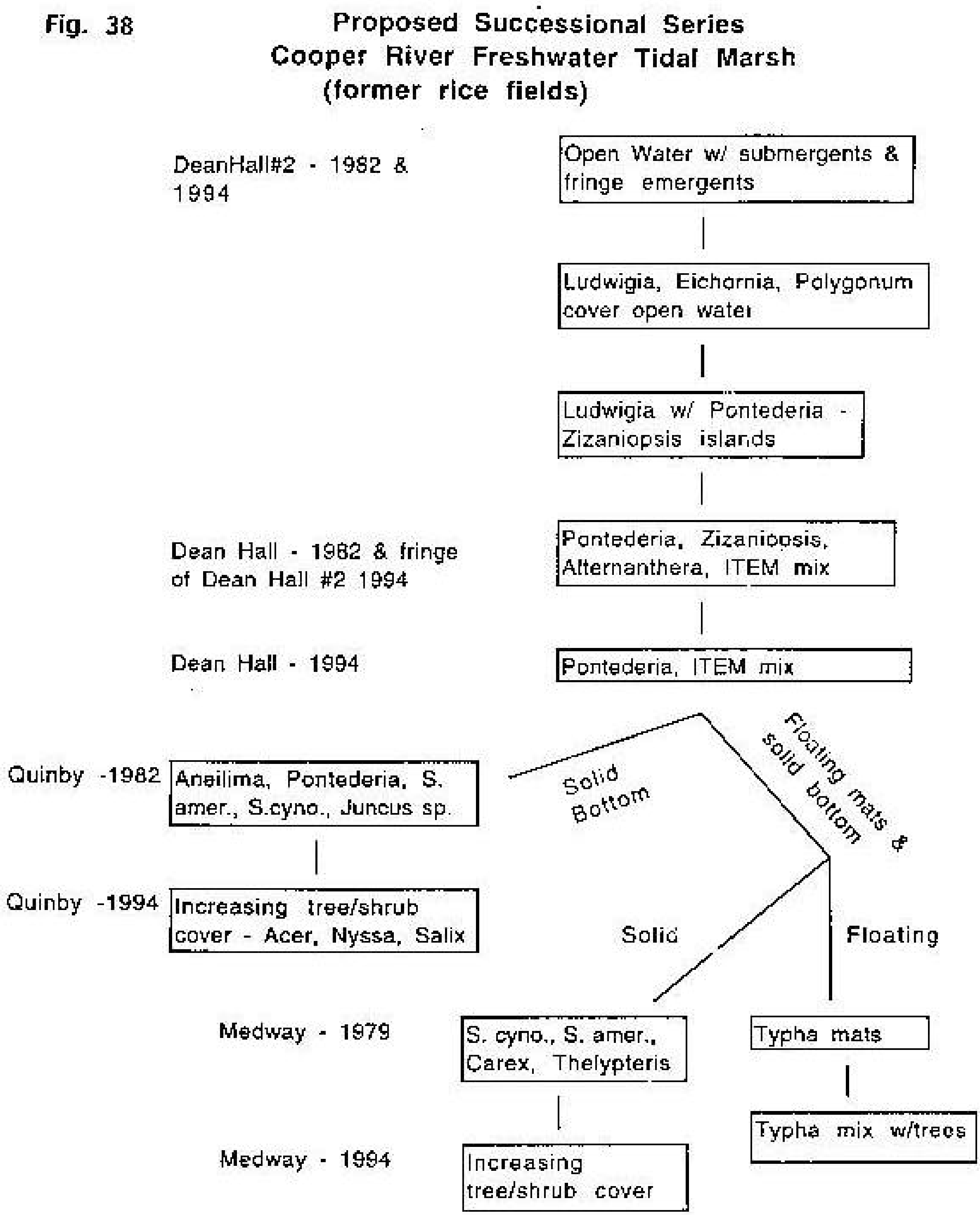


Fig. 38


Proposed Successional Series
Cooper River Freshwater Tidal Marsh
(former rice fields)
DeanHall#2 - 1982 & 1994
Open Water w/ submergents & fringe emergents
Ludwigia, Eichornia, Polygonum cover open water
Ludwigia w/ Pontederia - Zizaniopsis islands
Dean Hall - 1982 & fringe of Dean Hall #2 1994
Pontederia, Zizaniopsis, Alternanthera, ITEM mix
Dean Hall - 1994
Pontederia, ITEM mix
Solid Bottom
Floating mats & solid bottom
Quinby -1982
Aneilima, Pontederia, S. amer., S.cyno., Juncus sp.
Quinby -1994
Increasing tree/shrub cover - Acer, Nyssa, Salix
Solid
Floating
Medway - 1979
S. cyno., S. amer., Carex, Thelypteris
Typha mats
Medway - 1994
Increasing tree/shrub cover
Typha mix w/trees

General Observations on Vegetational Change in the Cooper System

The most impressive changes that have occurred in the Cooper system did not occur in the 4 fields we selected for quantitative sampling. Our ground level survey and low level flights showed large areas of previously open water fields, especially on the east branch, being covered by Ludwigia uruguayensis and Eichornia. Mild winters in the past decade have helped the expansion of these two species, which are controlled by hard freezes. Ludwigia has also taken advantage of lowered water levels to colonize slightly more elevated areas scattered throughout what were prerediversion Egeria flats. Waterways into and within fields that were open to fishing in 1982 are now closed. Ludwigia islands of 1982 can now be seen to incorporate Pontederia and Zizaniopsis plants. Zizaniopsis stands which were extensive throughout the system are giving way to mixtures of intertidal emergents. In the upper reaches of the east branch, Back River, Molly Branch and in diked fields at and above Mepkin, tree cover is becoming pronounced. Large areas of open water still predominate on many west branch fields; e.g., Strawberry, Mulberry, Bonneau Ferry and Pimlico.

Plant Species List and a Proposed Successional Pattern

Table 1 is a checklist of all vascular plants collected by Porcher from creek banks and freshwater intertidal areas along the upper Cooper system during the 1982 - 1994 period. Figure 38 presents a suggested successional pattern for the Cooper system based on our observations and measurements.

Discussion

It is clear that vegetational change in the freshwater water marshes of the upper Cooper River has accelerated since the rediversion. Stalter and Baden (1994) returned to three remnant rice fields near Georgetown, to assess change since 1968 (Baden et al., 1975). In that situation where no sudden change in succession driving factors has occurred, change is slow. They found few changes in species composition/distribution since their original study. In the Cooper system the sudden lowering of water levels led to measurable change in a variety of vegetational attributes over a 6 year period (Kelley, Porcher and Michel, 1990). The present study documents continuing change.

In preparing their fields for cultivation in tidal, rice growers attempted to level flat areas to get even depths of water coverage when they were flooded for weed control and the stretch flow (Doar, 1970). In many cases original elevations subsided after years of cultivation and erosion, making the fields difficult to drain. Fields near the downstream end of the freshwater tidal zone tend to be large, have low interior elevation and experience the greatest tidal range. When daily tidal flow returned as dikes failed, these fields became lake-like at high tide with interditch areas covered with submergents (Egeria and Cabomba) and emergents (Pontederia and Zizaniopsis) forming a fringe in shallow edge waters. Farther upstream where base elevations are higher and tidal range is smaller, the lake-like stage is either skipped or passed through quickly producing a field covered seasonally by broad leaf perennials (Pontederia, Cicuta and Peltandra) followed by grasses and sedges (Zizaniopsis and Scirpus sp.) and finally by mid-summer with a middle story of vines and other plants (Apios, Mikania, Lycopus, Alternanthera, Aneilima). These upstream fields are eventually invaded by trees tolerant of saturated soils (Acer, Salix, Baccharis, Myrica and Nyssa). To date all fields on the upper Cooper still have saturated soils on all tides.

Returning to downstream fields, the large open water fields accumulate sediments over time raising the elevations of the interditch flats and allowing rooted emergents to become established or, as in the case of the rediversion, water levels are lowered creating water cover patterns comparable to those that would result from bottom elevation due to sediment accumulation. Sediment depth and composition may be a factor in vegetational succession that is not replicated by lowering water levels but prerediversion sediments were thick (3 feet + and thicker than the depth of root penetration of the emergent plants growing on them) and at least had the appearance of uniform composition.

Over the period of the study in the Cooper system, one plant species, Ludwigia uruguayensis, seemed to have had the role of being the first rooted emergent to close open water areas. Interestingly, L. uruguayensis is not a factor on the South Edisto River where remnant rice field succession is also in progress. Ludwigia has a woody stem but depends on water buoyancy to provide much of its support. It can root in shallow areas and extend out over deeper water for a considerable distance. Since 1988, Eichornia (water hyacinth, a floating plant with short roots in water) has appeared and is spreading in both tidal and impounded fields. In 1994-95 we typically found it entangled with Ludwigia making a light blocking cover on the water surface and closing many areas of formerly open water to boaters. Pontederia and Zizaniopsis islands appear within the Ludwigia mats and expand outward as water depth permits. Fringing marsh also extends into Ludwigia mats. Further accumulation of sediments in dense rootmats or lowered water levels allow new species to invade Pontederia/Zizaniopsis stands leading to increased species complexity, less concentration of biomass among dominant species and a pattern of primary productivity marked by a series of seasonal peaks as different species reach their individual peaks. Eventually, Zizaniopsis thins from mixed stands at higher elevation leaving what we have termed the ITEM (intertidal emergent mix) which persists through tree invasion. One side pattern that is observed in deep ditches (Medway) or in impoundments that permanently hold water (fig. 2, fields along the east side of the west branch above Mepkin Abbey is the formation of a floating rootmat that traps enough sediment to allow the development of floating emergent communities that may even support trees and be free to move horizontally in the wind. In shallow flat fields the developing community is in firm contact with the substratum. Figure 38 summarizes these events.

Observations of the open water/Ludwigia mat fields suggest that they are especially attractive to wading birds, diving birds (especially ospreys and eagles), fishermen and hunters. We have also observed waterfowl using open areas behind blocked breaches and ditches as refuges. Dip net samples taken beneath these mats show concentrations of amphipods, cladocerans, ostracods, insect larvae, flatworms, snails and other invertebrates. In the late 1970s large flocks of ducks and coots occupied these areas from October to February. In the past decade, water fowl presence on the upper Cooper has steadily declined due in part to factors outside the region but also due to local factors including development of surrounding areas and increased boat traffic/disturbance throughout the year. Open water fields can also be seen to export large amounts of dead or broken pieces of Egeria on outgoing tides in every month of the year.

Mid successional stage fields with interditch areas covered by emergents are different from open water fields in their ecological functions, animal residents and recreational uses. At Dean Hall for example fiddler crabs/ burrows (Uca minax) are common but are absent from the open water field across the river (fig. 3, field#2) . Export of organic matter seems to be predominantly as fine detrital particles. Macrophyte primary production rates are high (Pickett, McKellar and Kelley, 1986) and the previous years standing crop has either become reduced to litter or tidally exported by the end of

February. Water fowl (especially wood ducks and mallards) are found in ditches at all tides and over the interditch areas on high tides. In the early 1980s hunters were frequently seen using the waterways provided by the ditches and the cover provided by the intertidal emergent plants to jump shoot ducks. Fishing is limited to breaches in dikes and deeper ditches. Continued recreational use of fields at this stage depends on whether or not waterways remain open.

Later stage fields; e.g., Quinby and Medway, are floristically more diverse than lower stage fields. Species appear that are generally considered to be terrestrial, for example, Rubus, Rhus and various trees. Animals found here are also more terrestrial than lower stage fields: copperhead snakes, rats, rabbits and deer. Ditches are filled in or closed by Ludwigia and Polygonum. Water fowl are scarce and human use is much less than in lower stage fields. Dominant plant species are more persistent after the winter die back and can be found standing well into the next growing season. Obvious detrital export appears to be reduced with most of the fields' decomposing organic matter seeming to stay in the field. As tree biomass increases, more of the productivity of the system becomes tied up in nonphotosynthetic support tissue. Runoff filtration is very likely greater in these later stage fields as the daily tidal water exchange budget is reduced.

The contribution of fields in different stages to the greater drainage basin is different and changes as succession proceeds. The profile of overall contribution of a particular stage to the greater system may be supportive to the health of the system at one point in time but less supportive to obvious needs later as succession replaces some functions. Some examples of functions that are stage dependent include:

1. specific habitat for endangered species
2. breeding habitat for game and non-game fish species
3. waterfowl refuges
4. export of primary production and timing of export
5. recreational opportunities for outdoorsmen
6. filtration of terrestrial runoff
7. amount and form of primary production
8. specific habitat for keystone invertebrate species
9. specific habitat for migratory species; e.g., striped bass, shad.

Remnant rice fields offer a unique opportunity for human intervention to preserve critical functions that are being lost to successional change. Dikes can be repaired and interiors managed to perpetuate these functions indefinitely.

Conclusions

1. Lowered water levels resulting from the rediversion project have accelerated vegetational succession in the freshwater tidal regions (remnant rice fields) of the upper Cooper River.

2. A proposed sequence of stages is presented in Figure 38.

3. The role played by different stages in the ecology of the drainage basin is different. Succession is therefore eliminating functions contributed by early stages and enhancing contributions made by later stages. Letting nature take its course is an active policy that may have detrimental consequences for the drainage basin.

4. The possibility of intervention to preserve functions identified to be critical is made feasible by the presence of repairable dikes. Human interventions in the ecology of the Cooper drainage basin are already numerous; e.g., dams blocking upstream access to breeding habitats, runoff from suburban, municipal and industrial development, disturbance by recreational users of waterways. Compensating interventions may be necessary to preserve system function and quality.

Recommendations for Further Research:

1. Identify specific functions of succession stages. Continue to track the accelerated process in the Cooper system.

2. Investigate the relationship between plant species/community presence and elevation so that rates of vegetational change can be modeled as a function elevation change (allows analysis of dynamics of sea level rise, sediment accumulation and water level management policy).

3. Develop a legal framework that will allow permitted repairs to strategically located fields with management conditions that accomplish ecological and recreational goals (perhaps, through a mitigation banking system).

Table 1

CHECKLIST OF VASCULAR PLANTS FROM THE COOPER RIVER, BACK RIVER, QUENBY CREEK AND HUGER CREEK, BERKELEY COUNTY, SOUTH CAROLINA

The following checklist of vascular plants represents plants collected from 1982 through 1995 by Richard D. Porcher from abandoned rice fields and river edges from the Back River, Western Branch and Eastern Branch of the Cooper River, Quenby Creek and Huger Creek. The specimens represent voucher specimens for field studies conducted by B. J. Kelley and R. D. Porcher. All specimens cited below are on deposit in The Citadel Herbarium. The number preceeding each specimen is Porcher's field collection number.

2013 *Spartina cynosuroides* (L.) Roth; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2014 *Ludwigia repens* Forster; Berkeley County; 10 September, 1982; abandoned rice field, MedwayPlantation, along west side of Back River; tidal freshwater marsh; CH.

2015 *Hypericum mitilum* L.; Berkeley County; 10 September, 1982; abandoned rice field, MedwayPlantation, west side of Back River; freshwater tidal marsh; CH.

2016 *Rhynchospora macrostachya* Torrey; 10 September, 1982; abasndoned rice fields, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2017 *Lippia nodiflora* (L.) Michaux; Berkeley County; 10 September, 1982; rice fields, Medway Plantation, along west side of Back River; fresh water marsh; collected for CRWU grant; CH.

2018 *Echinodorus cordifolius* (L.) Grisebach; Berkeley County; 10 September, 1982; rice fields, Medway Plantation, along west side of Back River; fresh water marsh; collected for CRWU grant; CH.

2020 *Lobelia cardinalis* L.; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of Cooper River; tidal freshwater marsh; CH.

2021 *Lippia lanceolata* Michaux; Berkeley County; 1 November, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2022 *Thelypteris palustris* Schoot; Berkeley County; 10 September, 1982; abandoned rice field, Medway Plantation, along west side of Back River; freshwater tidal marsh; CH.

2023 *Cyperus haspan* L.; Berkeley County; 1 October, 1982; abondoned rice fields, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2024 *Polygonum densiflorum* Meissner; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, along west side of Back River; freshwater tidal marsh; CH.

2025 *Juncus canadensis* J. Gay ex La Harpe; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, along west side of Back River; freshwater tidal marsh; CH.

2026 *Ludwigia palustris* (L.) Ell.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, along west side of Back River; freshwater tidal marsh; CH

2027 *Proserpinaca pectinata* Lam.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, along west side of Back River; freshwater tidal marsh; CH.

2028 *Scirpus cyperinus* (L.) Kunth; Berkeley County; 22 October, 1982; Medway Plantation, Back River; freshwater marsh in abondoned rice fields; CH.

2029 *Hypericum virginicum* L.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2030 *Aneilema keisak* Hasskarl; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2031 *Eupatorium capillifolium* (Lam.) Small; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2032 *Salix caroliniana* Marshall; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2033 *Osmunda regalis* var. *spectabilis* (Willd.) Gray; Berkeley County; 22 October, 1982; abandoned rice fields, Medway Plantation, along west side of Back River; freshwater marsh; CH.

2034 *Juncus roemerianus* Scheele; Berkeley County; 22 October, 1982; abandoned rice fields, Medway Plantation, along west side of Back River; freshwater marsh; CH.

2035 *Onoclea sensibilis* L.; Berkeley County; 22 October, 1982; abandoned rice fields, Medway Plantation, along west side of Back River; freshwater marsh; CH.

2036 *Cephalanthus occidentalis* L.; Berkeley County; 22 October, 1982; abandoned rice fields, Medway Plantation, along west side of Back River; freshwater marsh; CH.

2037 *Habenaria repens* Nuttall; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2038 *Ludwigia leptocarpa* (Nuttall) Hara; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2039 *Acer rubrum* L.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2040 *Liquidambar styraciflua* L.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2041 *Ludwigia uruguayensis* (Camb.) Hara; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2042 *Diodia virginiana* L.; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2043 *Nyssa sylvatica* var. *biflora* (Walter) Sargent; Berkeley County; 22 October, 1982; abandoned rice field, Medway Plantation, west side of Back River; freshwater tidal marsh; CH.

2044 *Ludwigia alata* Ell.; Berkeley County; 10 September, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2045 *Polygonum punctatum* Ell.; Berkeley County; 10 September, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2046 *Lycopus rubellus* Moench; 10 September, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2047 *Boehmeria cylindrica* (L.) Swartz; Berkeley County; 10 September, 1982; abandoned rice field, Medway Plantation, west side of Back River; tidal freshwater marsh; CH.

2048 *Cicuta maculata* L.; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh, CH.

2049 *Mikania scandens* (L.) Willd.; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2050 *Peltandra virginica* (L.) Kunth; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2051 *Alternanthera philoxeroides* (Martius) Grisebach; Berkeley County; 8 October, 1982; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2052 *Ipomoea sagittata* Cav.; Berkeley County; 8 October, 1982; abandoned rice fields, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2053 *Aster carolinianus* Walter; Berkeley County; 8 October, 1982; abandoned rice fields, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2054 *Cuscuta gronovii* Willd. ex R. & S.; Berkeley County; 8 October, 1982; abandoned rice fields, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2055 *Zizania aquatica* L.; Berkeley County; 8 October, 1982; abandoned rice fields, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2056 *Aster tenuifolius* L.; Berkeley County; 2 October, 1982; abandoned rice fields, Dean Hall Plantation, Western Branch of the Cooper River, freshwater tidal marsh; CH.

2057 *Cladium jamaicense* Crantz; Berkeley County; 29 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2058 *Kosteletzkya virginiana* (L.) Presl; Berkeley County; 29 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2059 *Eupatorium serotinum* Michaux; Berkeley County; 29 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2060 *Pilea fontana* (Lunell) Rydberg; Berkeley County; 29 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2061 *Impatiens capensis* Meerb.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2062 *Polygonum sagittatum* L.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2063 *Spiranthes cernua* (L.) Richard; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2064 *Amaranthus cannabinus* (L.) J. D. Sauer; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2065 *Solidago sempervirens* L.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2066 *Polygonum arifolium* L.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2067 *Eupatorium perfoliatum* L.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2068 *Eupatorium coelestinum* L. Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2069 *Apios americana* Medicus; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2070 *Lycopus rubellus* Moench; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2071 *Sacciolepis striata* (L.) Nash;; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2072 *Lythrum lineare* L.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2073 *Habenaria repens* Nuttall; Berkeley County; 1 October, 1982; abandoned rice fields, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2074 *Verbena scabra* Vahl; Berkeley County; 1 October, 1982; abandoned rice fields, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2075 *Erianthus giganteus* (Walter) Muhl.; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation on Quenby Creek; freshwater marsh; CH.

2076 *Aster puniceus* L.; Berkeley County; 1 October, 1982; abandoned rice fields, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2077 *Scirpus americanus* Persoon; Berkeley County; 1 October, 1982; abandoned rice field, Quenby Plantation on Quenby Creek; freshwater marsh; CH.

2078 *Rhynchospora corniculata* (Lam.) Gray; Berkeley County; 1 October, 1982; Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2079 *Bidens laevis* (L.) BSP.; Berkeley County; 1 October, 1982; abandoned rice fields, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2080 *Pluchea camphorata* (L.) DC.; Berkeley County; 22 October, 1982; Medway Plantation; abandoned rice fieldss west side of Back River; freshwater tidal marsh; CH.

2212 *Impatiens capensis* Meerb.; Berkeley County; 27 September, 1988; Dean Hall rice fields, Western Branch of Cooper River; freshwater tidal marsh; CH.

2213 *Bidens laevis* (L.) BSP.; Berkeley County; 27 September, 1988; Dean Hall rice fields, Western Branch of Cooper River; freshwater tidal marsh; CH.

2214 *Polygonum arifolium* L.; Berkeley County; 27 September, 1988; Dean Hall rice fields, Western Branch of Cooper River; freshwater tidal marsh; CH.

2215 *Lycopus rubellus* Moench; Berkeley County; 27 September, 1988; Dean Hall rice fields, Western Branch of Cooper River; freshwater tidal marsh; CH.

2216 *Aneilema keisak* Hasskarl; Berkeley County; 27 September, 1988; Dean Hall rice fields, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2217 *Mikania scandens* (L.) Willd.; Berkeley County; 24 August, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2218 *Zizania aquatica* L. Berkeley County; 25 August, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2219 *Amaranthus cannabinus* (L.) J. D. Sauer; Berkeley County; 20 August, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2220 *Apios americana* Medicus; Berkeley County; 20 August, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2221 *Lythrum lineare* L.; Berkeley County; 20 August, 1988; abandoned rice field, Dean Hall, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2222 *Polygonum sagittatum* L.; Berkeley County; 20 August, 1988; abandoned rice field, Dean Hall, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2223 *Cicuta maculata* L.; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2224 *Alternanthera philoxeroides* (Martius) Grisebach; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2225 *Pontederia cordata* L.; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2226 *Hibiscus moscheutos* L.; Berkeley County; 15 July, 1988; abandoned rice fields, Dean Hall, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2227 *Ludwigia uruguayensis* (Camp.) Hara; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2228 *Scirpus americanus* Persoon; Berkeley County; 1 June, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; CH.

2229 *Ptilimnium capillaceum* (Michaux) Raf.; Berkeley County; 19 June, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2230 *Eryngium aquaticum* L. var. *aquaticum*; Berkeley County; 5 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; tidal freshwater marsh; CH.

2231 *Sium suave* Walter; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; CH.

2232 *Spartina cynosuroides* (L.) Roth; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2233 *Cladium jamaicense* Crantz; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River, freshwater tidal marsh; CH.

2234 *Juncus effusus* L.; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; first identified as *Scirpus validus* by Porcher; CH.

2235 *Galium obtusum* Bigelow; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; CH.

2236 *Lippia lanceolata* Michaux; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of Cooper River; freshwater tidal marsh; CH.

2237 *Peltandra virginica* (L.) Kunth; Berkeley County; 24 July, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; CH.

2238 *Cyperus pseudovegetus* Stuedel; Berkeley County; 17 July, 1988; abandoned rice field, Dean Hall, Western Branch of Cooper River; freshwater tidal marsh; CH.

2240 *Sacciolepis striata* (L.) Nash; Berkeley County; 27 September, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; CH.

2241 *Orontium aquaticum* L.; Berkeley County; 25 August, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2242 *Rumex verticillatus* L.; Berkeley County; 19 June, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2243 *Lobelia cardinalis* L.; Berkeley County; 15 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2244 *Ipomoea sagittata* Cav.; Berkeley County; 24 July, 1988; abandoned rice field, Dean Hall Plantation, Western Branch of the Cooper River; freshwater tidal marsh; CH.

2359 *Cabomba caroliniana* Gray; Berkeley County, South Carolina; 22 July, 1994; tidal freshwater marsh, Quenby Creek; CH.

2360 *Eryngium aquaticum* L. var. *aquaticum*; Berkeley County; 22 July, 1994; tidal freshwater marsh, Quenby Creek; CH.

2361 *Physostegia leptophylla* Small; Berkeley County, South Carolina; 22 July, 1994; tidal freshwater marsh, Quenby Creek; CH.

2367 *Saggitaria latifolia* Willd.; Berkeley County, South Carolina; 29 July, 1994; tidal freshwater marsh, Huger Creek; CH.

2368 *Lippia lanceolata* Michaux; Berkeley County, South Carolina; 29 July, 1994; tidal freshwater marsh, Huger Creek; CH.

2369 *Rhynchospora corniculata* (Lam.) Gray; Berkeley County, South Carolina; 29 July, 1994; tidal freshwater marsh, Huger Creek; CH.

2370 *Scirpus americanus* Persoon; Berkeley County, South Carolina; 29 July, 1994; tidal freshwater marsh, Huger Creek; CH.

2385 *Eupatorium serotinum* Michaux; Berkeley County, South Carolina; 15 September, 1994; tidal freshwater marsh along Cooper River; CH.

2386 *Hypericum walteri* Gmelin; Berkeley County, South Carolina; 15 September, 1994, tidal freshwater marsh along Cooper River; CH.

2387 *Aeschynomene indica* L.; Berkeley County, South Carolina; 15 September, 1994; edge of Quenby Creek at Hammer Boat Landing; CH.

2388 *Boltonia caroliniana* (Walter) Fernald; Berkeley County, South Carolina; 22 September, 1994; tidal freshwater marsh along French Quarter Creek; CH.

2389 *Habenaria repens* Nuttall; Berkeley County, South Carolina; 22 September, 1994; tidal freshwater marsh along French Quarter Creek; CH.

2390 *Sagittaria lancifolia* L.; Berkeley County, South Carolina; 22 September, 1994; tidal freshwater marsh along French Quarter Creek; CH.

2479a *Sagittaria subulata* Buch. var *subulata*; Berkeley County; 1 August, 1995; former rice field of Dean Hall Plantation, Western Branch of the Cooper River; rooted in creek bottom that runs through the field; CH.

2480a *Potamogeton* sp; Berkeley County; 1 August, 1995; former rice field of Dean Hall Plantation, Western Branch of the Cooper River; submerged in creek running through rice field; CH.

2517 *Verbena scabra* Vahl; Berkeley County; 9 August, 1995; former rice field of Medway Plantation, Back River; freshwater tidal marsh; CH.

2518 *Commelina virginica* L.; Berkeley County; 9 August, 1995; former rice field of Medway Plantation, Back River; freshwater tidal marsh; CH.

2519 *Echinodorus cordifolius* (L.) Grisebach; Berkeley County; 9 August, 1995; former rice field of Medway Plantation, Back River; freshwater tidal marsh; CH.

2520 *Najus gracillima* Magnus; Berkeley County; 9 August, 1995; Back River adjacent to Medway Plantation; submerged, freshwater; CH.

2539 *Cynoctonum mitreola* (L.) Britton; Berkeley County; 17 August, 1995; abandoned rice field of Quenby Plantation along Quenby Creek adjacent to SC-98; freshwater tidal marsh; CH.

2540 *Ludwigia alata* Ell.; Berkeley County; 17 August, 1995; abandoned rice field of Quenby Plantation along Quenby Creek adjacent to SC-98; freshwater tidal marsh; CH.

2541 *Vernonia noveboracensis* (L.) Michaux; Berkeley County; 17 August, 1995, abandoned rice field of Quenby Plantation along Quenby Creek adjacent to SC-98, freshwater tidal marsh; CH.

2542 *Ceratophyllum demersum* L.; Berkeley County; 17 August, 1995, Quenby Creek near SC-98; submersed; CH.

2566 *Cuscuta gronovii* Willd. ex R. & S.; Berkeley County; 17 August, 1995; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh; CH.

2567 *Rhynchospora caduca* Ell.; Berkeley County; 17 August, 1995; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2568 *Eleocharis microcarpa* Torrey; Berkeley County; 17 August, 1995; abandoned rice field, Quenby Plantation, Quenby Creek; tidal freshwater marsh; CH.

2587 *Cyperus haspan* L.; Berkeley County; 17 August, 1995; abandoned rice field, Quenby Plantation, Quenby Creek; freshwater tidal marsh, CH.

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